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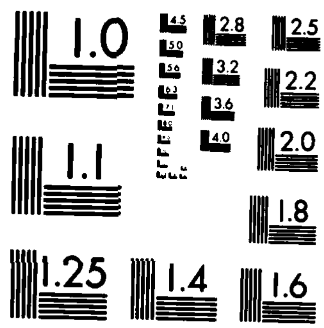

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AVIONICS INTEGRITY ISSUES PRESENTED DURING NAECON 1984

Compiler/Editor:
Harold C. Fortna, First Lieutenant, USAF
Avionics Integrity Program Office

December 1984

TECHNICAL REPORT ASD-TR-84-5030

Final Report for Period 21 May 1984 to 25 May 1984

Approved for Public Release; Distribution is Unlimited.

DIRECTORATE OF AVIONICS ENGINEERING
AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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This technical report has been reviewed and is approved for publication.

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FOR THE COMMANDER

Gary L. Ludwig

GARY L. LUDWIG
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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report summarizes the failure modes (chemical, mechanical, or thermal) which reduce the operational life of avionic and electronic equipment. Lt Gen Thomas H. McMullen's speech at Tuesday's luncheon summarizes the history of avionics and presents the great importance of avionics to the future of aircraft.

The notes from the management session, ASD Integrity Thrusts, discuss the important aspects of avionics integrity in design, manufacturing, and use. The important role people play in the development and manufacturing of an electronic product is shown. Stress screening of electronic components is important to having quality equipment and is discussed from the government's perspectives of maintenance and supply as well as from the view of the Institute of Environmental Sciences (IES).

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18. Screening (ESS), Failure Modes, Corrosion, Thermal Management, Combined Environmental Reliability Testing (CERT).

19. Finally, the present effort by the government to ensure quality electronic products, the Avionics Integrity Program (AVIP) is discussed in the notes from an open forum/panel at the management session and is presented in great detail through the notes of the AVIP tutorial session at NAECON.

PREFACE

Technology has brought us to the point where electronics are becoming pervasive on all new aircraft. Because these electronics are both expensive and critical to mission success, it is necessary to look at the integrity of these electronics if aircraft are to be ready to fly and fight. Hence, the theme of the 1984 National Aerospace and Electronics Convention (NAECON) was "Operational Readiness Through Electronic Integrity". Integrity is an evolution from such presently used measures as reliability and maintainability to the newer concepts of durability (lifetime), supportability, availability, quality and producibility. In the Air Force, all of these are important to the operational readiness of our aircraft and to the reduction of the cost of operating and maintaining our aircraft.

Also, the use of avionics is expanding into flight critical systems onboard our aircraft. Therefore, it is necessary to improve avionics integrity for flight safety as well as mission accomplishment.

In support of the NAECON theme, ASD engineering supported a number of events at NAECON. A tutorial about the Avionics Integrity Program was presented on Monday, May 21. Notes from the tutorial were published as a separate document with NAECON sponsorship and are duplicated at the end of this report.

A second event concerning avionics integrity was the Tuesday luncheon speech presented by Lt Gen Thomas H. McMullen. EN Product Assurance personnel assisted in the preparation of this speech. A transcript of the speech is included in this report.

Third, the five technical sessions listed below were organized around the theme of integrity.

A. Manufacturing Quality and Maintainability

B. Reliability

C. Life Cycle Cost

D. Avionics Environment

E. Electromagnetic Compatibility

The papers for these technical sessions are published in the NAECON 1984 proceedings. It should be noted here that the Best Paper Award went to one of the papers of the Reliability technical session. Mr. Edward Banas and Mr. Charles Chappell of Sperry Corporation co-authored this best paper entitled "Integrating Chip Carrier Packaging Technology into Systems."

Finally, the ASD Integrity Thrusts management session was organized and presented by the EN Product Assurance Office. This session explored the following three topics of the management of reliable/supportable avionic systems.

a. Fatigue failure modes of avionics

b. Electronic piece part quality and environmental stress screening

c. The Avionics Integrity Program

The notes and viewgraphs from this management sessions are contained in this report.

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Lt Gen McMullen's Tuesday Luncheon Speech

As an overview to the ASD Integrity Thrusts management session notes, the following transcript of a speech presented by Lt Gen Thomas H. McMullen on 22 May 1984 has been included in this report. This speech was presented by Gen McMullen at Tuesday's Luncheon at NAECON 1984.

Remarks to: NAECON 84' Dayton, Ohio, 22 May 1984

Speaker: Lt Gen T. H. McMullen

It's a real pleasure for me to be invited back to this luncheon and to be given the opportunity to discuss developments in electronics. The theme of this years NAECON, Operational Readiness Through Electronic Integrity, is not only timely but it is emerging as perhaps the key developmental concern as our Air Force moves toward the Year 2000. Right off the top I want to straighten out a misconception. It has been said by some that ASD has always tried to adhere to the sumo wrestler school of management with regard to electronic programs. They say our motto is "Throw your weight around but keep your rear end covered." While I can't pin it down exactly, I have reason to believe this characterization of ASD was started by an IEEE member. Well, in any case it's wrong. It's not ASD you're thinking of--it's AFLC.

During lunch I was reflecting a bit on the Chaplin's words -- thinking about you folks and the vital nature of your work. Those thoughts conjured up the story of a retired, former IEEE member who was reclining under a tree. A passerby (I believe he was a particularly observant engineer) shouted, "Your house is on fire." "I know it," the old timer said. The engineer said, "Why don't you do something about it?" The ex-IEEE member said, "Doing something now -- I've been prayin for rain since the fire started." Now, I have no doubt prayer helps, but you folks know better than anyone else that direct, innovative and sustained action goes a long way to help those prayers get answered.

I believe all of us in the business of electronics count as Ogden Nash's loudest critics when he said, "Progress might have been alright once, but it's gone on too long." While there are new and exciting things happening throughout the spectrum of "high tech" development, no single area is moving forward at the tremendous rate that we see in electronics. Charles Kettering once said, "The Wright brothers flew right through the smokescreen of impossibility." Today, my organization, like the ones you represent, is finding the way through that same smokescreen. I guess that's why I feel so comfortable with this group. We share a common bond. For taking the first tentative steps through any new frontier has always required courage, foresight, and ingenuity -- characteristics represented in spades by the people in this room. Other institutions are also going through tremendous changes. In this respect we share a common bond of experience with several commercial institutions such as Dayton's NCR Corporation. As many of you are no doubt aware, the likes of the cash register, business machine, and key pieces of office equipment have completed a transition from mechanical to electronic systems within the past decade. It seems only fitting that we are meeting here in Dayton as NCR is celebrating its 100th anniversary.

While there are a lot of things I'd like to talk about, I have tried to keep my remarks to a reasonable length as I'm sure you're all anxious to get on with the day's business.

Our preoccupation with time reminds me of a story that came out of Poland during the 1982 riots -- and perhaps typifies some of the logic in a police state under martial law. Of course, you recall that the government set a strict curfew holding that all citizens would be off the streets and in their homes by 6 p.m. or risk being shot. It seems it was 10 minutes to 6:00 when a policeman went up to a fellow waiting at a bus stop -- looked him over -- pulled out his revolver and shot him. Killed him with one shot. Immediately a crowd of people circled the policeman asking why he had killed the man. The policeman said, "Hey, I know where this guy lives -- there is no way he could get home by 6 p.m." If I do make you run a bit over, I hope the penalties aren't as severe at an IEEE luncheon.

Ulysses S. Grant told us, "The art of war is simple enough. Find out where your enemy is. Get at him as soon as you can. Strike him as hard as you can and as often as you can, and keep moving on." I like his style -- and I must admit that not much has changed in war fighting philosophy. What has changed are the tools at our disposal to do the fighting.

And clearly, none of them have changed over the last 70 years as much as fighter aircraft and the avionics systems that make them so effective. It began with men hurling insults and bricks at one another from open cockpits, and moved to ever faster turning, close-in dog fights. But today, if we do our work right, two fighter pilots may take each other on without ever visually seeing one another before they fire their weapons.

The use of electronics on-board aircraft -- avionics -- is nearly as old as powered flight and certainly its changes have played a key role in the development of flight. One of the first radio telegraph messages was sent from a signal corps aircraft to the ground in November 1912. The aircraft, one of the twelve in our signal corps, was piloted by a young Lieutenant named "Hap" Arnold. Just a few years later, in August of 1917, the first two-way radio telephone contact from the air was made by the Army. As in most things aeronautical, our "bicycle shop" at Wright Field has been instrumental in achieving a number of avionics firsts through the years. The first solo flight on instruments was made here in 1932 and the first completely automatic landing in history was completed here in 1937.

War brought a need for rapid, innovative solutions to numerous avionics related problems and necessarily spurred many avionics developments. The British demonstrated an experimental aircraft interception radar in June of 1939 -- and by the end of September of that same year, 30 systems had been installed in British aircraft. Avionics had grown to a point where systems helped provide the margin of victory during the Battle of Britain. Even then, however, the safety and survivability of the aircraft in the early years of aviation did not depend upon the integrity of the avionics as they do today.

In those early years, the avionics constituted only a small fraction of the gross empty weight of the aircraft. The avionics package on the P-38 and P-51 weighed less than two percent of the total aircraft's empty weight. The avionics on the F-86 I flew in Korea was still less than two percent of the total. But as our expectations for our aircraft grew so did weight. The F-106A avionics topped ten percent with its reliance on vacuum tubes in the late 1950s. In the 1960s and 1970s, we were able to reverse the weight growth of avionics. The introduction of solid state electronics in the F-111A, F-16A, and the F-18 enabled us to approach 6 percent of the aircrafts empty weight with dramatic increases in performance and reliability. For a typical subsystem, performance capability has increased concurrently with a major decrease in weight. For example, an early UHF command radio, the ARC-34 built in 1954 weighed 50 lbs versus 9 lbs for the ARC-164 introduced in 1975. This weight reduction was achieved even though the number of operating channels was doubled and the flying hours between needed repairs increased ten-fold.

Today's avionics frontiers are characterized by both technology and complexity. As technological advances enable us to reduce the size and weight of an avionics subsystem we continue to add more functions to our list of requirements for our systems thus adding to the overall complexity of the challenge. This relationship between technology and complexity can be illustrated in a quick review of airborne radars. The MG-13 radar on the F-101B used about 7000 parts, 421 of which were vacuum tubes. This radar averaged about 4.0 flying hours between failures. The APQ-120 radar on the F-4E used nearly 14,000 parts and only 24 of these were vacuum tubes. This radar, an example of discrete transistor technology, averaged 7.0 flying hours between failures. Today our F-15C and D APG-63 radar represents the microcircuit technology of the seventies. It is made up of about 19,000 parts, averages 23 flight hours between failures and was a pioneering application of multilayer printed wiring boards. It represents a giant step in performance as well as reliability. It's true, we've had to make some hard tradeoffs and will doubtless face the same choices in the future, but the payoff in reliability and effectiveness makes it all worthwhile. In the case of the APQ-120 it's meant a five-fold increase in life despite a three-fold increase in complexity.

Some express concern that the complexity of technology will overwhelm our ability to use it. To me, it's just the opposite. If we do it right, I believe it is becoming apparent that an important characteristic of technology will have to be its simplicity -- simple to fly; simple to fight; simple to maintain. That is just the combination we are seeking. By way of example, nowhere will this characteristic of simplicity be more important than in the fighter cockpit of the future. As the sophistication of our fighters has grown, we have created some marvelous systems to "help" the pilot. But there's a lot more to do, because he's doing about as much as he can right now.

You know, WWI aircraft had 10 to 15 controls and instruments. During WWII, the P-51 cockpit had about 35. Today, the F-15 has over 300 dials, bells, buzzers, lights, and switches in the cockpit. Pilots are at the saturation point. In our rush to help, we have built in lots of information to manage during the "breath holding" few seconds of combat, but we need to do a lot more to help tomorrow's pilot determine his targets (the good news) and his threats (the bad) without pushing a lot of distractions at him. As many of you know we are trying to do something about this problem right now. Through a number of laboratory programs at ASD, we are blending an array of technologies, trying to integrated them into a total system. Integration of <u>all</u> on-board systems is a must if we're to improve the pilot's ability to manage his systems in concert.

Innovation in avionics will be critical if we are to continue moving forward -- staying ahead of that ominous "power curve" our adversaries would like desperately to put us behind. Innovation in avionics has already dramatically changed the effect of air power in warfare and nothing in my crystal ball tells me anything is going to change for the future. Improved navigation capability allows us to fly to the engagement site with minimum error. Our radar warning receivers and electronic countermeasures systems have allowed us to penetrate to target areas protected by increasingly sophisticated electronic defenses. Improvements in radar have extended our vision to let us acquire and track targets at even greater standoff ranges. And our weapon delivery systems allow us to effectively put ordance on the target at night and under the weather.

Today we are in the midst of a major revolution in our aircraft -- a transition from the mechanical to an electromechanical system. We will have completed that transition when we field our next fighter, the Advanced Tactical Fighter or ATF, in the mid-1990s.

The ATF is clearly good news for our Air Force. The bad news is that ATF is already about four years farther behind the F-15 than the F-15 was behind the F-4 in development. We have a lot of catching up to do.

The ATF will have capabilities that will pulse the full range of avionics systems. We look for this airplane to not only achieve supersonic speed, but to be able to stay there long enough to cover some ground. It'll have a range 50 to 100 percent greater than the F-15 Eagle's; ability for short take-off and landing, to get in and out of damaged airfields; obviously, the ability to engage multiple enemy fighters at once, beyond visual range; and it will have to survive while doing all that in an environment filled with people, in the air and on the ground, who want to kill him. And we want it to be operated by a single pilot. If it all sounds like it will be enormously difficult, I'm making my point.

As concerns the Air Force of today and tomorrow, this electronics revolution I've been discussing will take final form as improved technology which created new options for improved capabilities to guarantee our persistence of the battlefield. That is the ability to fight around the clock, in all weather. It will be a key test for the organizations you folks represent -- both on the corporate side and military side. Our ability to fight will involve more than "how high, how fast, and how far." It must also address "how often." How often are America's fighting machines ready to fight rather than out for maintenance or lack of parts. It is one question where a poor answer could well be our loss. Let me illustrate. Let's consider a typical fighter aircraft. Current avionics equipment consists of Line Replaceable Units, or LRUs. A typical LRU has about 100 hours Mean Time Between Failures. This typical LRU has a 98 percent chance of lasting through a 2-2 1/2 hour mission.

But say there are 25 LRUs per aircraft. That means 46 percent of the aircraft land with a system failure. Each failed box could (and often does) result in several box removals for bench testing. The LRUs are tested in the avionics intermediate shop to determine which unit to change. The technician finds the problem, removes and replaces the suspect unit, sends it back to the depot for repair, retests the LRU, and puts it back on the shelf as a spare.

While there is no doubt the avionics intermediate shop has permitted us to operate with modest reliability to this point, it represents a significant burden that we literally have to carry around on our back. It is big -- it takes over four C-141B's to deploy a wing's worth of the F-16 intermediate shop -- our smallest system. It is complex. It is expensive. It is manpower intensive. And -- it is vulnerable. I'll tell you right now, if the avionics intermediate shop is knocked out, we can plan on losing capability faster to avionics failures than to combat losses. Eighty-four percent of the aircraft I used in my earlier examples will land with a failed box by the end of a day under the demands of wartime use. I must therefore conclude that a 100 hour Mean Time Between Failure of an LRU is just not good enough.

The consequences of poor reliability are three-fold. First: it burdens the field commander with the vulnerability and difficulty of carrying the avionics shop around with him. Second: it takes a huge chunk of the budget to keep us in spare parts. In fact, the budget for replenishment, spares, and modifications to patch old electronics exceeds that of developing new electronics. Third: Demands for manpower to purchase, stock, transport, install, and in some cases repair spare parts are substantial. And for each mechanic with hands on our weapon systems, there are many others required for support and training.

We are making a hard charge at lessening the dependence we have on the avionics intermediate shop by incrementally improving reliability and using built-in test capability inside of the avionics equipment. As the diagnostic capability of this built-in test equipment approaches that of the in house avionics shop, we can begin to position our systems without all the extra baggage. We are making progress -- right now for example, 50 percent of F-16 repairable avionics items do not require the use of the avionics shop.

Improvements in avionics have been steady to this point. However, we are at the beginning of a new chapter in development of our Air Force. A chapter whose outline tells us improvements may slow drastically, perhaps not occur at all if it requires cost in dollars, time, or combat effectiveness.

To help ensure that we do continue to see improvements, ASD is restructuring its avionics development and reliability program. We call it the Avionics Integrity Program. It incorporates the technical and programmatic elements of the highly successful Air Force Structural and Engine Integrity Programs combined with the traditional electronics parts data base. This reorientation of our avionics development approach reflects the recognition that electronic systems function until a mechanical or chemical failure causes an electrical failure. The Avionics Integrity Program will be discussed on Wednesday afternoon by Dr. Halpin, my director of product assurance, and Mr. Ludwig, ASD's technical director for Avionics Engineering. Technology growth through the VHSIC or Very High Speed Integrated Circuit, is a major element of our Avionics Integrity Program. VHSIC offers the potential for significant performance improvements through increased computational speed. Increased computational speed is achieved through reducing inter-component distances -- this means significantly reduced feature sizes on the chips themselves. I'm convinced that VHSIC is critical to successful implementation of all our future flying systems. There is a potential to markedly improve hardware reliability if some of the resulting reduced volume is reinvested to reduce the operating stresses on the electronic equipment, as always, an opportunity for tough trades and difficult decisions. We believe that solid engineering, in both design and manufacturing, combined with continued technology growth, can produce systems of significantly improved reliability -- without significant penalties in cost, schedule, or combat performance. Our discussions with industry about VHSIC support the contention that significant improvements are available at modest cost. We recognize several things are necessary to make it happen. First: insistence on reliability by our program offices combined with the Avionics Integrity Program. Second: competition based on reliability. Third: some reorientation of contract policy to encourage expenditures to upgrade equipment and procedures. These initiatives involve the industrial modernization, GET, PRICE, and Value Engineering programs. And fourth:

retraining of many design and manufacturing engineers.

There is an opportunity for leadership here. That opportunity exists on both sides of the table. The payoff will be long in coming, hence it is difficult to sustain attention to action over the long haul. But both are necessary to successfully complete the electronics transition as we move toward the future.

Well, I can see the time is growing short so rather than risk finding out the penalty IEEE bestows on a speaker who carries on too long, I'd better end my remarks here.

Thank you again for this opportunity to talk to you and I'll keep my fingers crossed for the opportunity for a return engagement next year.

Thank you and have a great week.

Dr. John Halpin, ASD's Assistant for Product Assurance, moderated the ASD Integrity Thrusts management session. An outline of this session is shown below. Dr. Halpin's introductory remarks were similar to the opening remarks of his presentation at the AFSC Horizon South conference the next day. In order to be more complete, Dr. Halpin's entire Horizon South presentation is included in this report.

ASD INTEGRITY THRUSTS

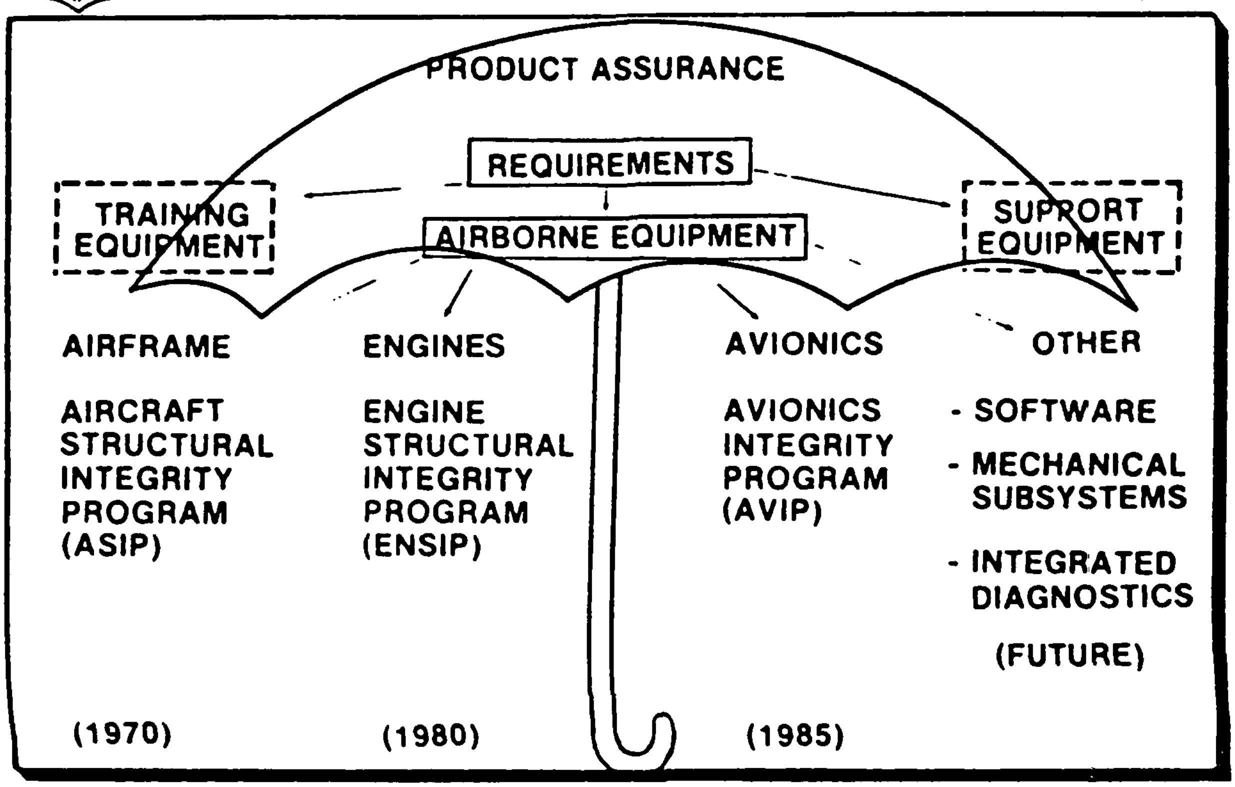
1. INTRODUCTION	Dr. John Halpin ASD/EN(PA) Wright-Patterson AFB, OH 45433
2. MECHANICAL FAILURE MODES FOR ELECTRONICS (videotapes)	Mr. Dave S. Steinberg Litton Guidance and Control Systems Woodland Hills, CA
	Dr. John K. Hagge Collins Defense Communications Div. Rockwell International Cedar Rapids, IA 52498
3. THERMAL DESIGN OF ADVANCED AVIONICS	Dr. Ajay Sharma Dept. 489 Bldg 300-41B East Fishkill Facility, Route 52 Hopewell Junction, NY 12533
4. FAILURE MODES	Mr. John Devaney 911 S. Mountain Ave. Monrovia, CA 91016
5. USE OF STRESS SCREENING AT THE DEPOT	Mr. Ed Koenig WRALC/MAIE Robins AFB, GA 31098
6. STRESS SCREENING OF MIL-STD COMPONENTS	Col Dalton Wirtenan Defense Electronics Supply Center DESC-E Dayton, OH
7. STRESS SCREENING: THE INSTITUTE OF ENVIRONMENTAL SCIENCES' PERSPECTIVE	Mr. C.E (Neil) Mandel, Jr. Radar Systems Group Hughes Aircraft Company P.O. Box 92426 Los Angeles, CA 90009
8. THE AVIONICS INTEGRITY PROGRAM and PANEL DISCUSSION	Mr. Gary Ludwig ASD/ENA Wright-Patterson AFB, OH 45433

ASD PRODUCT ASSURANCE FOR AVIONICS/ELECTRONIC SYSTEMS

J. C. HALPIN
ASSISTANT FOR PRODUCT ASSURANCE
AERONAUTICAL SYSTEMS DIVISION

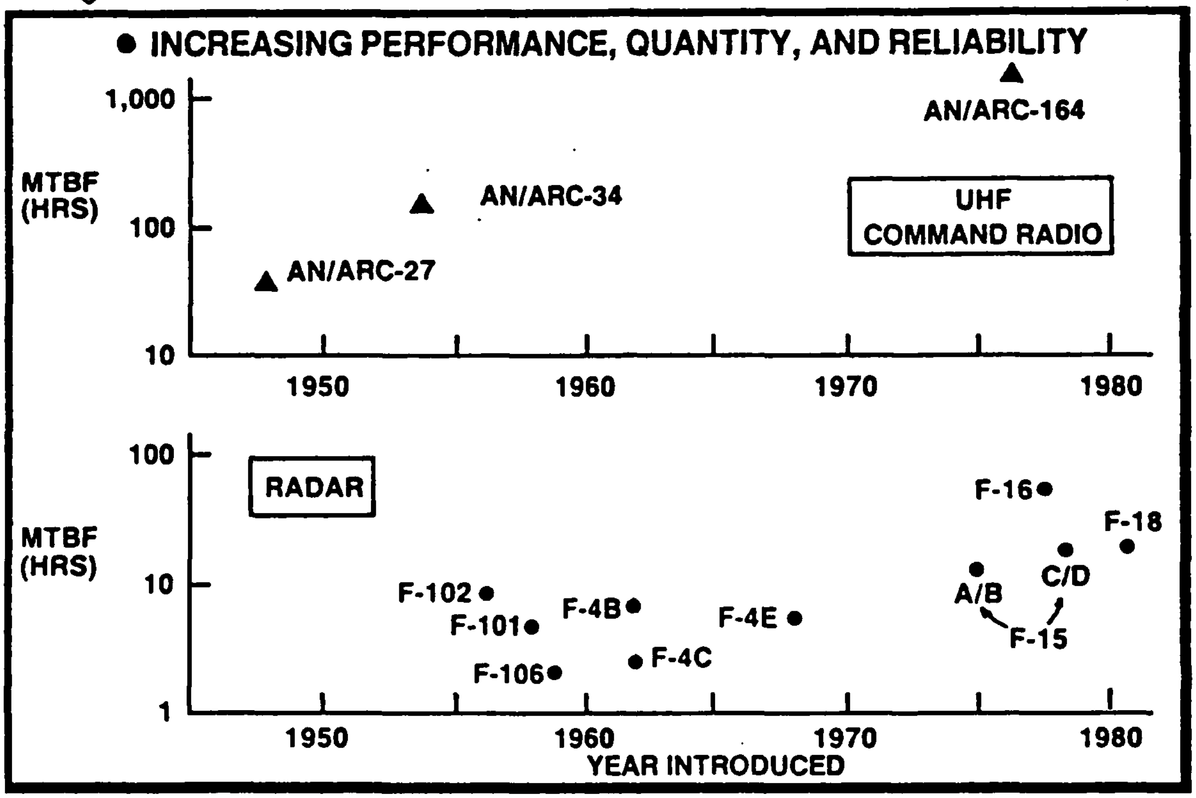
#1. Avionics integrity is a phrase which may be foreign to some of you. We have a long tradition, however, in the systems area with what we call our integrity programs. We have a tradition that starts before World War II when we were addressing safety and performance in airframes and how we would govern and manage those in the acquisition process. This grew through the second world war. In the fifties, we were forced to face the fact that airframes have finite lives, dictated by something other than combat attrition. This brought in the concept of life limited by fatigue processes. This concept was formally incorporated in the design, development, and acquisition process in the 50's with formal requirements for fatigue testing, like a reliability qualification test.

PRODUCT ASSURANCE



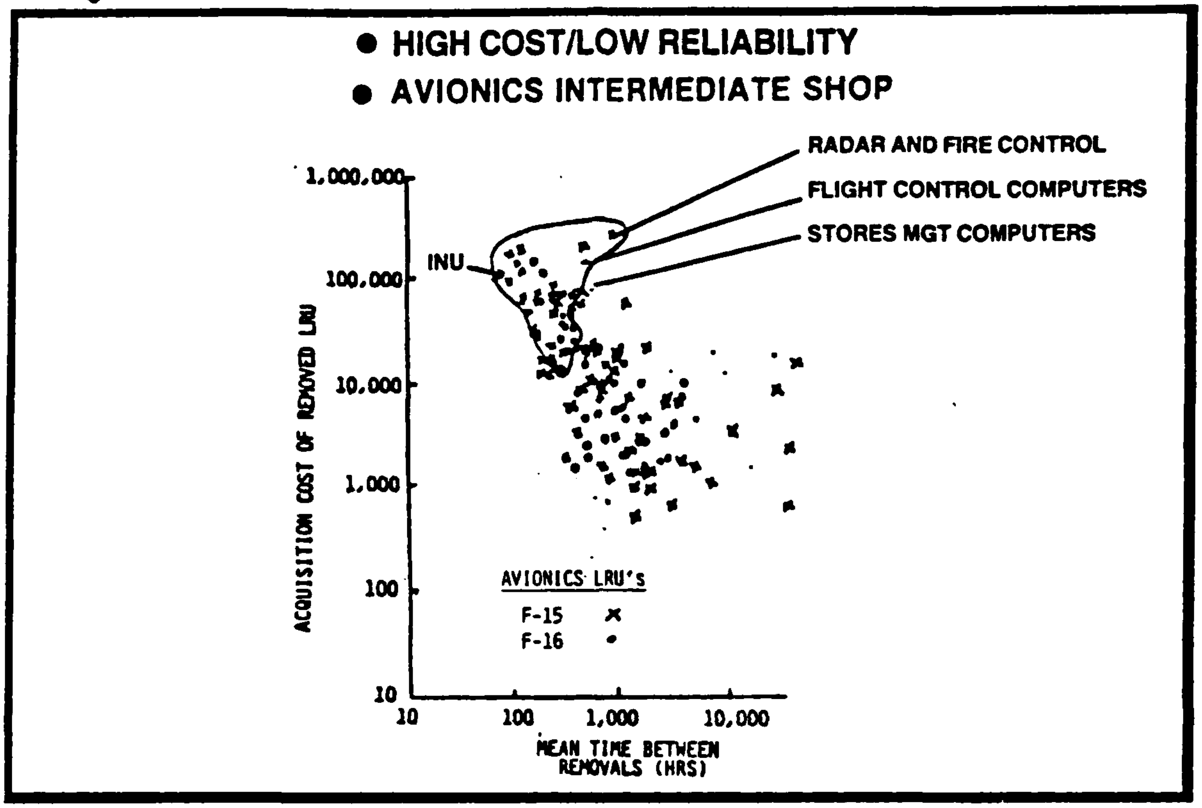
#2. We had additional problems in the 60's. We lost several airplanes due to fractures in the wing structure and the fuselage. We reformulated the structural integrity program at that time, adding formal fracture control. That became the basis of the current aircraft structural integrity program. It's also the technical basis for the certification processes for all civil aircraft in this country and in Europe. After that matured, that technology base was transitioned into engines, starting in the mid-1970's. As late as the F-100 development program, we tended to specify engines in terms of operating hours---no specifications in terms of throttle motions or thermal cycles of the engine. The engine integrity program took the mechanical fracture process, converted it into a thermal fatigue analysis for the engine parts, emphasized a fracture control process in the engines and applied it beginning in the late 70's. That is the baseline to which we are acquiring the new engines in our system. As the technology base matures and as electronics and avionics have become critical and essential to aircraft performance, we are looking at formalizing the avionics development activities in a similar format as we have done on engines and in the airframe. We feel that a natural evolution is taking place in industry maturing disciplines like reliability and maintainability into a more deterministic integrity approach as used in structures and engines. We must accept the fact that the avionics is a major subsystem which is critical to the aircraft itself and needs to be managed with the same intensity and commitment that we manage airframe and engines. It is basically a systems engineering process. We're going to emphasize attention to some of the physical failure modes as well as to good conservative electrical systems design. Our discussion today, then, will emphasize this area. We have segregated mechanical design and electrical design from software quality and reliability as we believe you must understand the physical status of the system and the electrical status independent of the software, and those must be matured separately and then put together in a system analysis activity.

EVOLUTION OF TYPICAL AVIONICS SUBSYSTEMS



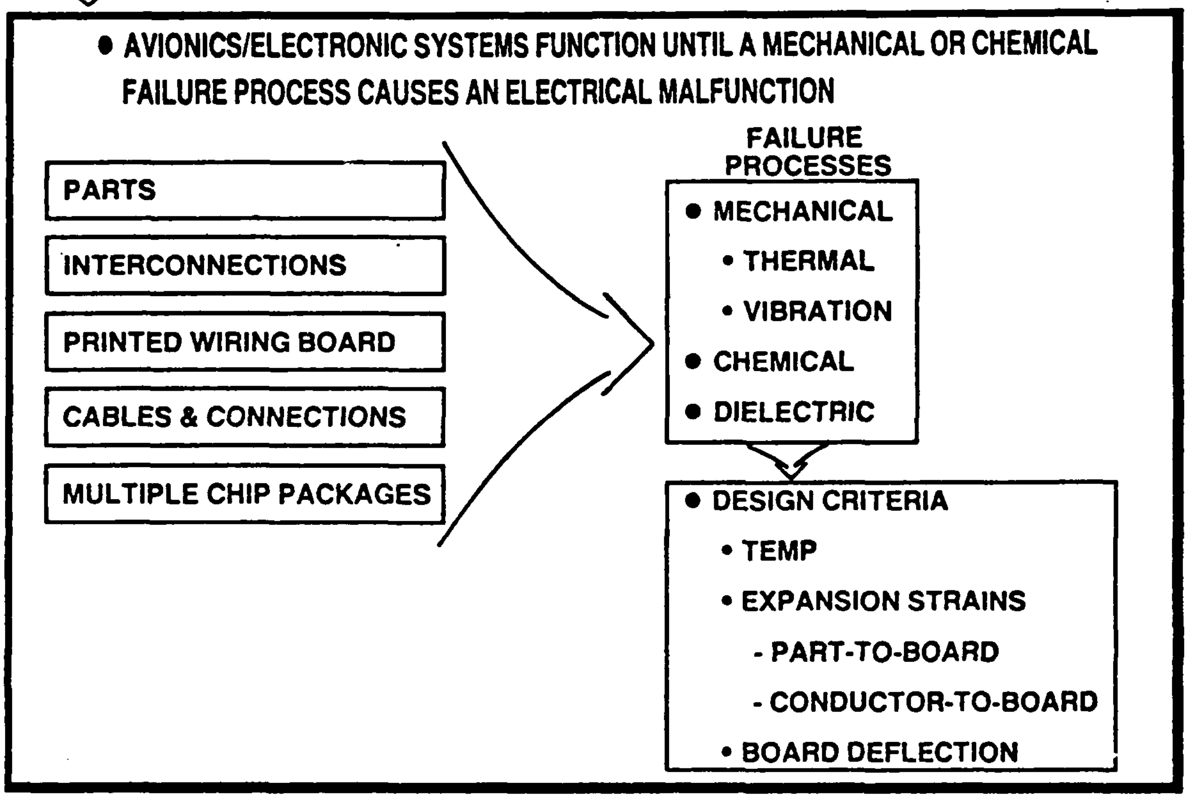
#3. We have continued to develop avionics systems with ever increasing requirements for performance and reliability. Often, we sacrifice some equipment ruggedness or maintainance features in order to meet the demanding performance requirements. In communications systems we have been able to achieve sizable improvements on several fronts. The AN/ARC-34 introduced in 1954 weighed 50 pounds, was designed with vacuum tubes, and was crystal controlled. The AN/ARC-164, by contrast, was introduced in the mid 1970's and weighs only 9 pounds. It is totally solid state and is fully frequency synthesized. The reliability of the AN/ARC-164 represents a factor of 10 improvement over that of the AN/ARC-34. In radar subsystems, the increasing performance demands keeps the designers working just to keep up and, consequently, we see *only* modest increases in system reliability. To illustrate the point, the MG-13 introduced on the F-101 contained 7000 parts, 421 of which were vacuum tubes. The APQ-120 radar on the F-4E used 13,000 parts. Only 24 vacuum tubes were used. By the mid 1970's when we developed the APG-63 radar for the F-15 A/B, the performance demands had quadrupled. The APG-63 incorporated 19,000 parts in its largely solid state design. We have still managed some modest system reliability improvements even with the very demanding performance requirements of today.

GROWING PAINS



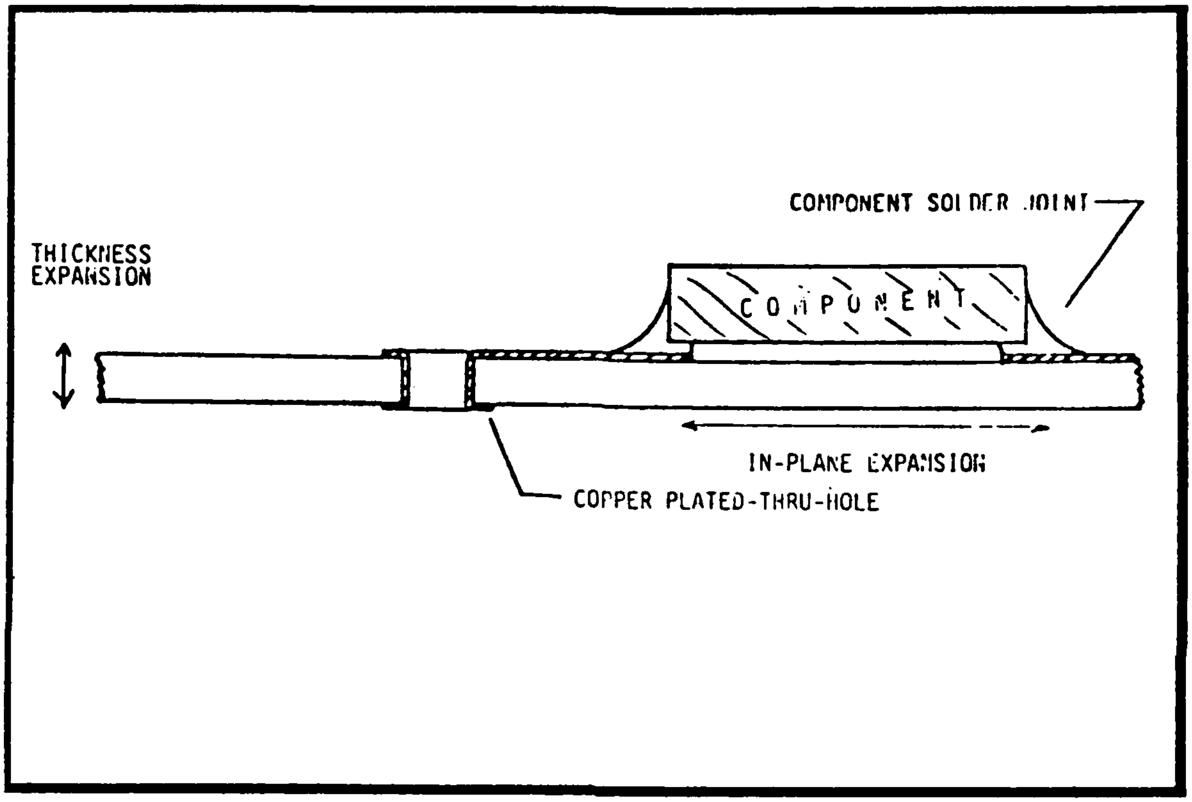
#4. The next chart shows that while we have had a very positive and growing experience, we've been suffering growing pains. In this chart, instead of a system, we have an assemblage of black boxes called line replaceable units. The problem that we have in managing the system is that the units which have been critical to performance on the battlefield are typically the systems at the upperleft. These kinds of systems have very low reliability at relatively high cost. Today, some of these boxes with reliabilities of 100 to 300 hours cost over a million dollars an LRU. They're driving the requirements for the AIS (Avionics Intermediate Shop), for our spares, for our manpower. It's handling these directly that is motivating our management to put firmer attention into the LRU's represented by the enclosed area. Traditionally, we have developed LRU's with a set of technical tools which represent good conservative electrical engineering practices supplemented with piece part analysis based upon MIL-HDBK-217. One of the problems we have had is the life predictions. The reliability predictions have been piece part oriented and we have had poor correlation between those predictions and field results. As a consequence, we have had a lack of confidence in some of our designs and that lack of confidence has frustrated attempts to make some of the hard decisions to go for a conservative design. It's building this confidence by putting in additional tools which is what we are emphasizing as one of the major technical thrusts in our evolution of the Avionics Integrity Program.

FAILURE PROCESSES



#5. The next chart represents a somewhat extreme position, but the chart is intended to make a point. When we have mature, well-developed electrical designs we still have failures, in the factory and in the field. When we have properly addressed electrical design, those failures tend to be mechanical and chemical in origin. It is those failures with which we are having difficulty in addressing today's design methodology. They occur at a series of levels: parts, the interconnections between the parts and the boards, failure modes within the printed wiring boards, in the cables and connectors, and multichip hybrid packages which are a combination of all these problems together. We believe that most of these areas can be treated in a formal way very similar to the techniques people are using to get qualitative guidelines to design mechanical and thermal packaging today. We feel that these failure processes can be grouped in these classifications. Criteria such as the derating temperatures, expansion strains between the part and board and the conductor and board, and board deflections govern fatigue processes. When analyzed as failure processes, we believed that you can design a better product and make suitable trades for a longer lifetime, and that's the message and the theme of our integrity program.

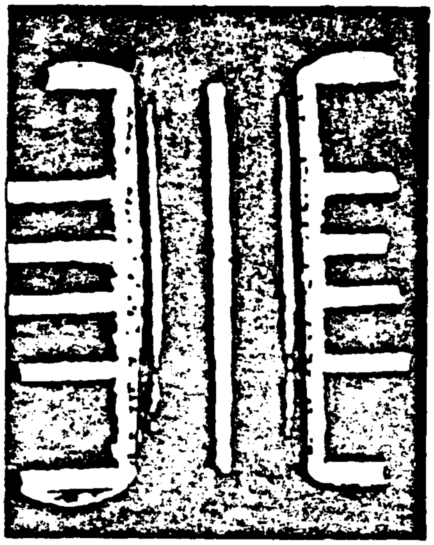
TYPICAL THERMAL FATIGUE FAILURE LOCATIONS

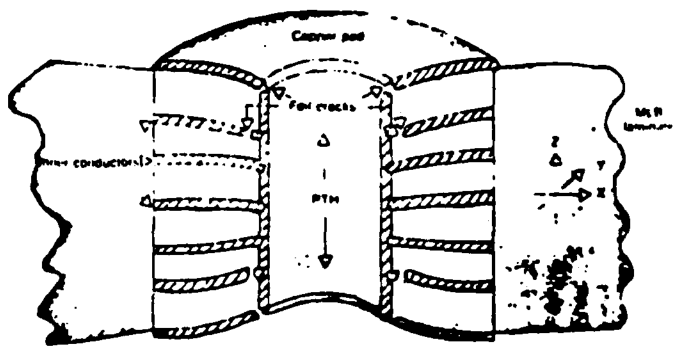


#6. An example of a mechanical failure process at work in our systems is thermal fatigue. Thermal cycling encountered in the ground and airborne operational environment is at work not only on the components but also at the interfaces of the components to the printed wiring board. Shown here is a plane view of a multi-layer printed wiring board showing typical fatigue failure locations. The strain in solder joints, particularly for surface mounted devices, cause fatigue failures which appear often as on open electrical connection. In surface mount applications the solder forms both the electrical and mechanical joint. There is no lead to carry a share of the stress. Expansion can often be five times greater than the in-plane expansion for G-10 glass epoxy printed wiring boards. The strain induced in the copper plated through hole can lead to a number of fatigue related failures shown in the following pictures.

THERMAL FATIGUE FAILURES

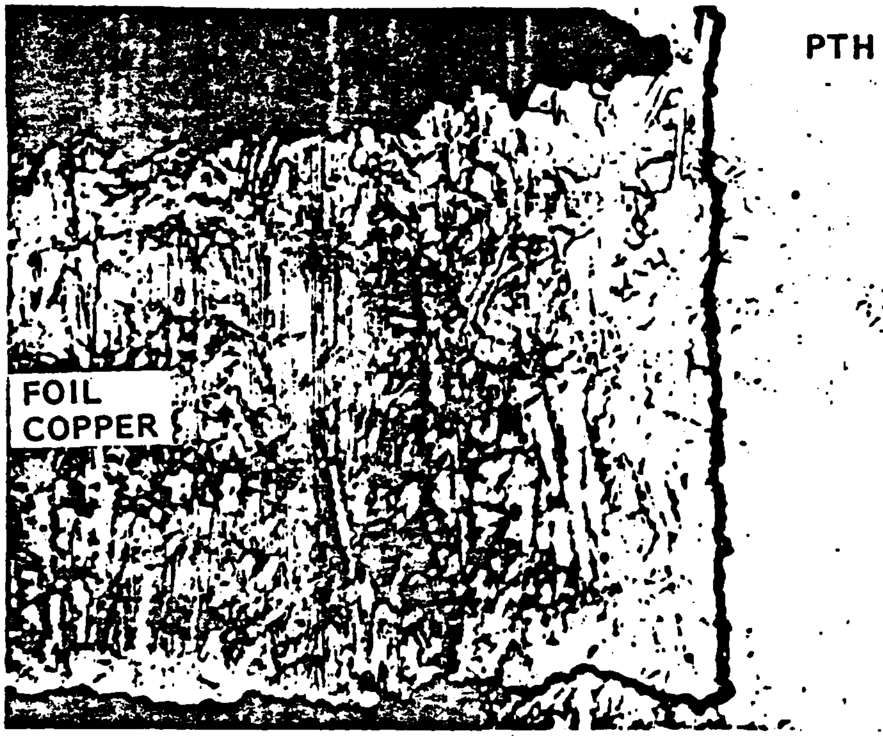
- **PLATED THROUGH HOLES/MULTILAYER PRINTED WIRING BOARDS**





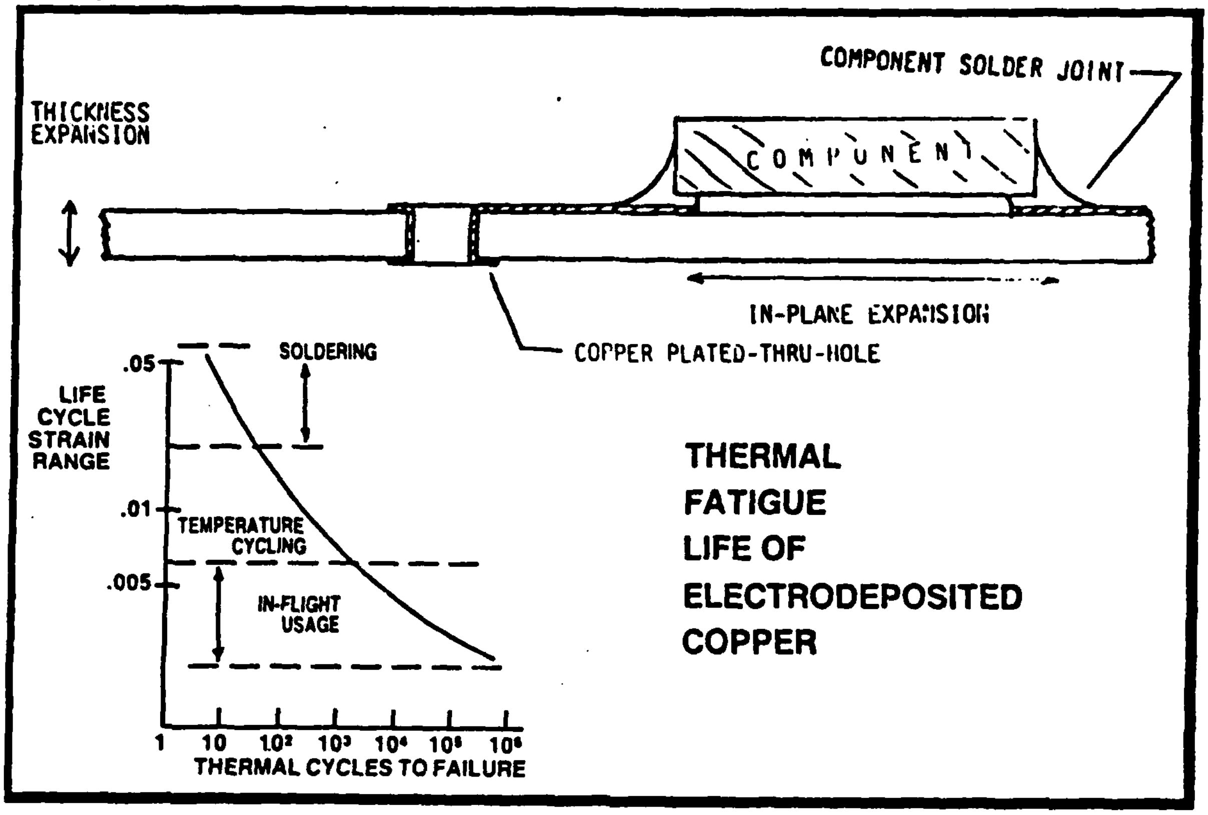
#7. Here is photo of an actual plated-through-hole in cross section. Stress concentrations at the interface between the copper plated barrel and the inner conductors often lead to foil cracks, as shown in the drawing on the right, when the board expands out-of-plane.

CRACKED CONDUCTION IN PRINTED WIRING BOARD



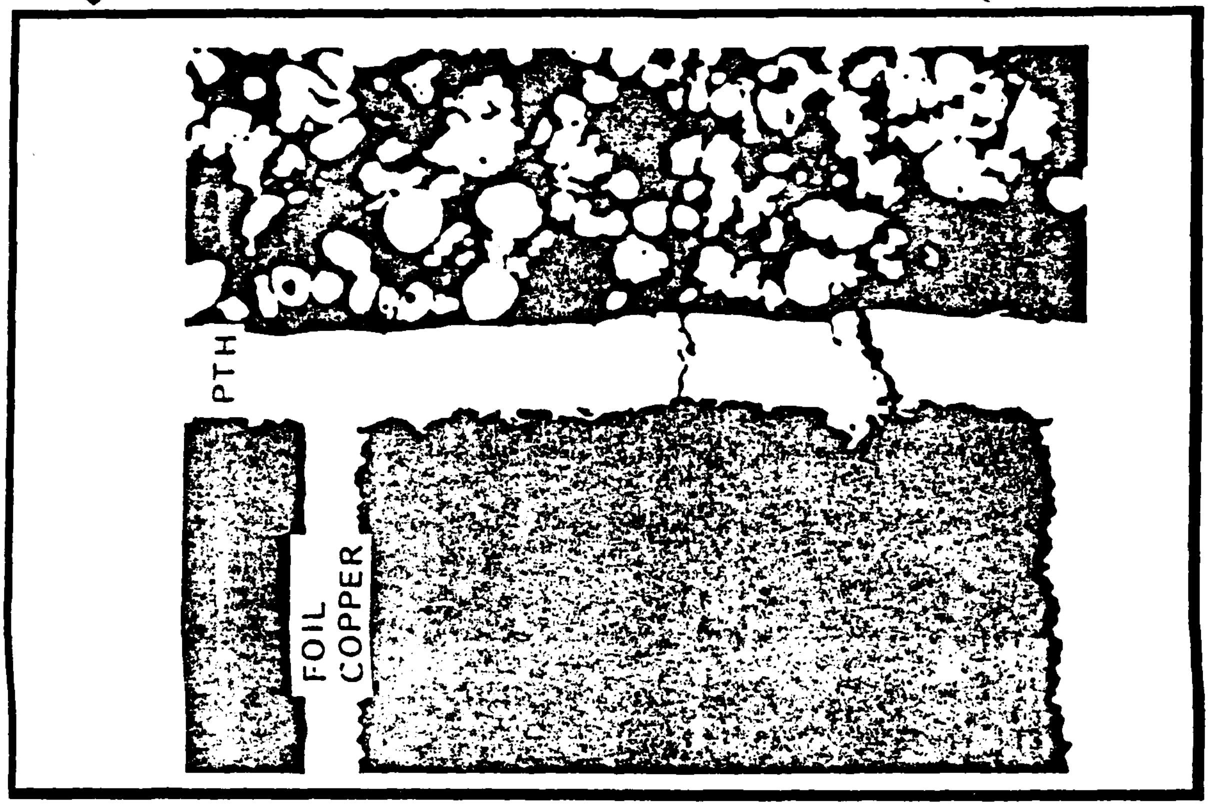
#8. Here is a photo of an actual foil crack at the interface with the plated-through-hole.

TYPICAL THERMAL FATIGUE FAILURE LOCATIONS



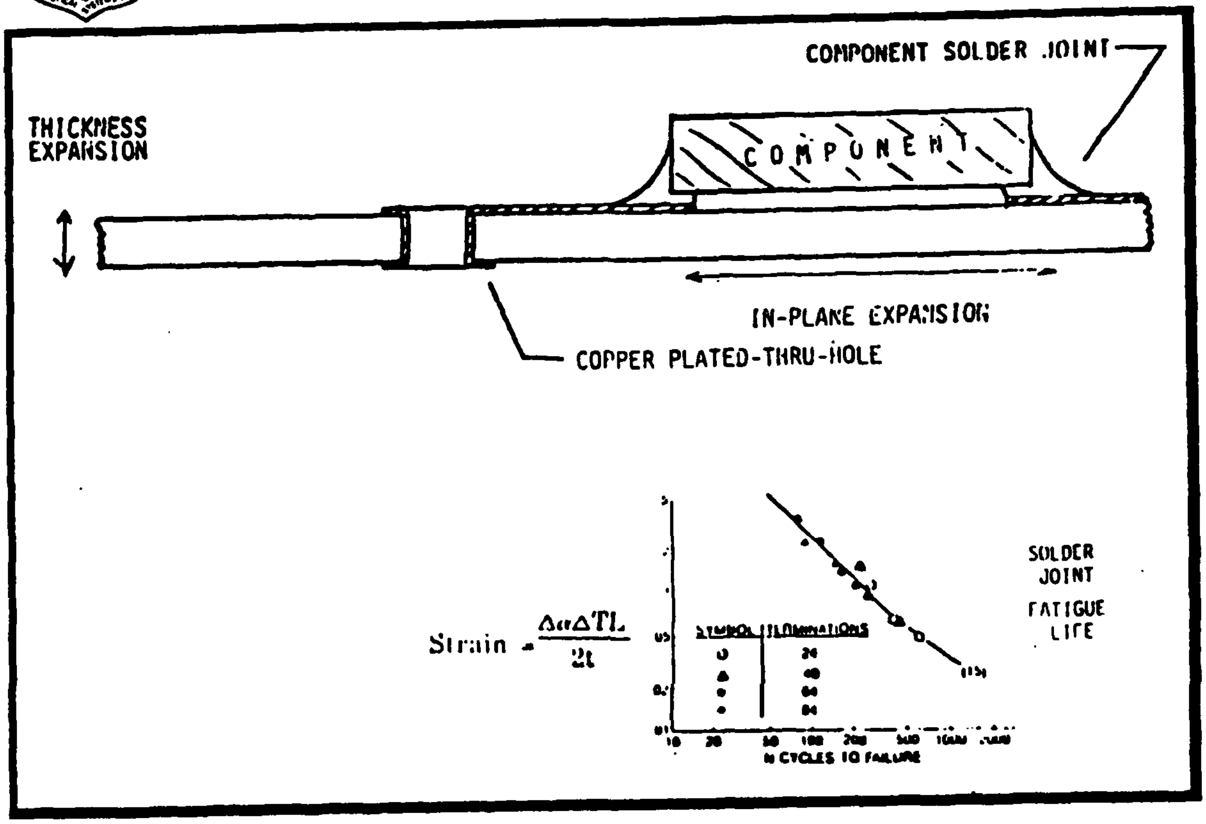
#9. Thermal cycles contributing to fatigue failure can be induced during manufacturing and repair as well as during during operational usage. The strain levels experienced during the repair cycle can be five to ten times the levels experienced during in flight usage. As shown on the chart at lower left, these strain levels can significantly reduce the lifetime of the copper.

CRACKED PLATED THROUGH HOLE



#.10. Here is a photograph of the cracked electrodeposited copper in the barrel of the plated-through-hole due to thermal fatigue.

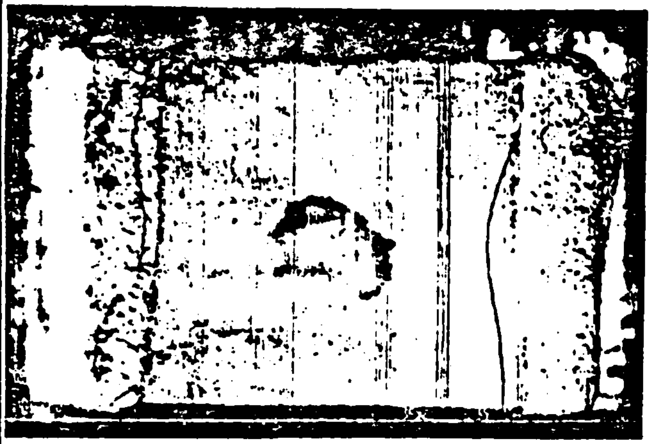
TYPICAL THERMAL FATIGUE FAILURE LOCATIONS



#11. The strain in the solder joint can be determined when the strain/failure relationship of the solder is known or is measured. The number of thermal cycles to failure can be predicted. Shown in the lower right is a plot of experimental failure data for several common leadless chip carrier packages. The line is as predicted by the strain equation.

THERMAL FATIGUE FRACTURES

- CERAMIC CHIP CAPACITOR
- LEADLESS CHIP CARRIER



FAILED AT 100 CYCLES* DUE TO CONTAMINATED JOINT

FAILED AT 100 CYCLES *: 68 PIN CHIP CARRIER/POLYIMIDE BOARD

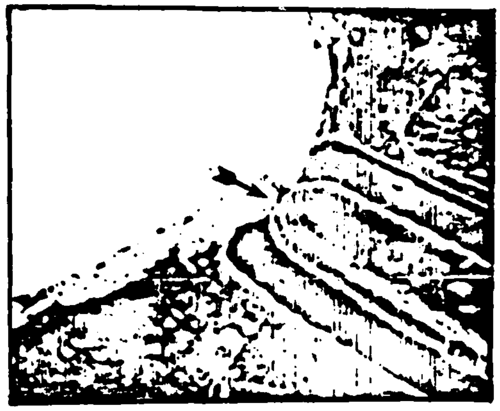
* TEMP. CYCLING FROM −55 TO 125°C

#12. Shown here are two examples of solder joint failure. The ceramic chip capacitor was gold coated to aid in solder adhesion but the gold contaminated the solder leading to embrittlement and subsequent cracking. The picture on the right shows clear cracking of each solder joint after 100 temperature cycles on this leadless chip carrier.

ELECTRONIC PART FAILURE

- **TYPICAL FAILURES ON CHIP SURFACE**

CRACK/FRACTURE OF METALLIZATION PATH

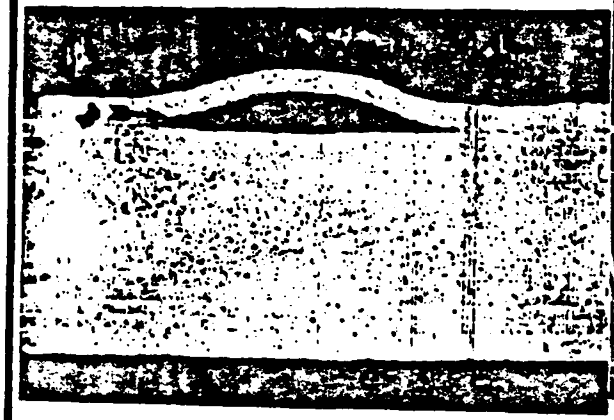


INTERMETALLIC FORMATION UNDER GOLD BOND AND SHORTING ACROSS METALLIZATION PATHS

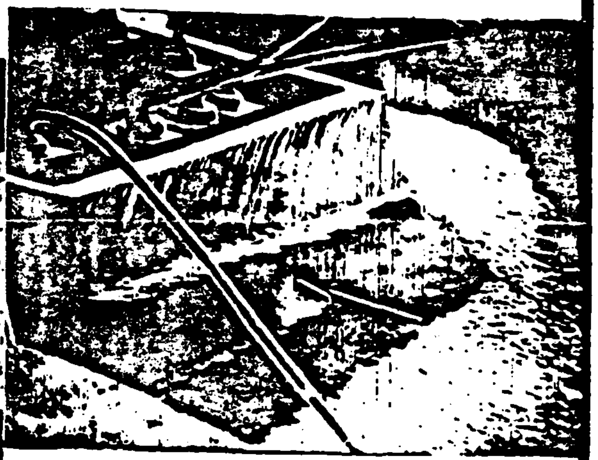
#13. The failures are not confined to the interfaces between components and boards. Shown here are scanning electron microscope (SEM) photos taken of chip level failures. A stress concentration exists at the point where two metallization runs overlap. Here, the stress concentration resulted in a crack across the metallization and resulted in an open circuit. The intermetallic growth pictured on the right forms when two metals such as gold and aluminum are present in a moist, elevated temperature environment. Conditions are often good for this formation in poorly sealed integrated circuit packages. The result - an internal electrical short.

ELECTRONIC PARTS FAILURES

- **FRACTURE OF BONDED SURFACES**



DELAMINATED CERAMIC CAPACITOR



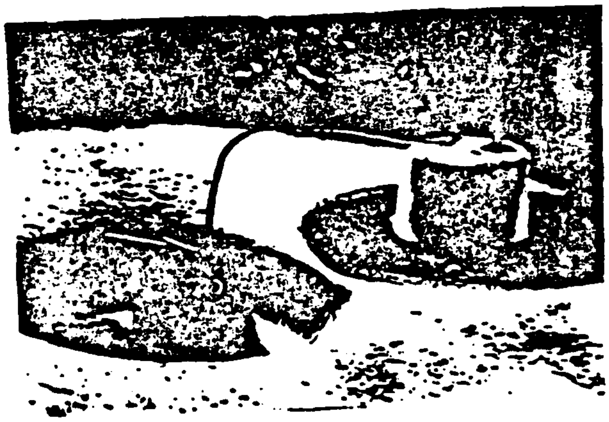
I. C. CHIP DEBONDING FROM CASE

#14. More component failures are shown here. In the case on the left moisture expanding at high temperature caused delamination in the capacitor stack. On the left, the integrated circuit die has become detached from the header. It is being held in place by the bonded wire interconnections. The adhesive may not have been applied properly. Even though the chip may be operating electrically, it will fail for lack of heat transfer from the die or from breakage of the interconnection beads in the vibration environment.

ELECTRONIC PARTS FAILURES

• THERMAL FATIGUE: FLYING GOLD LEADS

THERMAL FATIGUE CRACKING



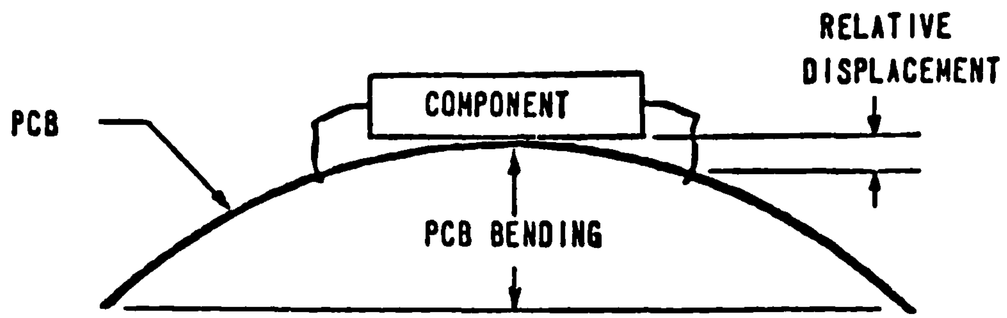
INADEQUATE THERMAL STRAIN RELIEF

#15. Shown at the left is a classic case of thermal fatigue related cracking of an integrated circuit lead within the package. Inadequate strain relief shown at the right can cause this problem.

PRINTED CIRCUIT BOARD (PCB)

FAILURES OCCUR IN COMPONENT LEAD WIRES AND SOLDER JOINTS DUE TO BOARD BENDING

- **MECHANICAL FATIGUE FAILURES**



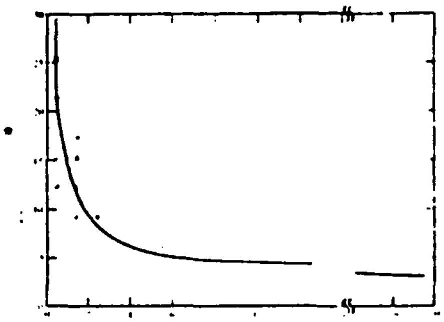
- **FATIGUE LIFE GOVERNED BY BOARD DEFLECT AND DEFECTS**

#16. We have spent a large portion of our allotted time talking about thermal related fatigue mechanisms. There are mechanical fatigue failures caused by vibration mechanisms. Shown in this viewgraph is an edge view of a printed wiring board constrained at the edges but allowed to deflect in the center. Limiting the allowable board deflection can increase the lifetime of the printed wiring boards. Dave Steinberg from Litton Guidance and Control Division in Woodland Hills, California has published a good text on designing avionics packages to survive operational vibration which causes fatigue fracture of component leads attached to the board.

A TYPICAL CABLING FAILURE

- STRESS CORROSION CRACKING

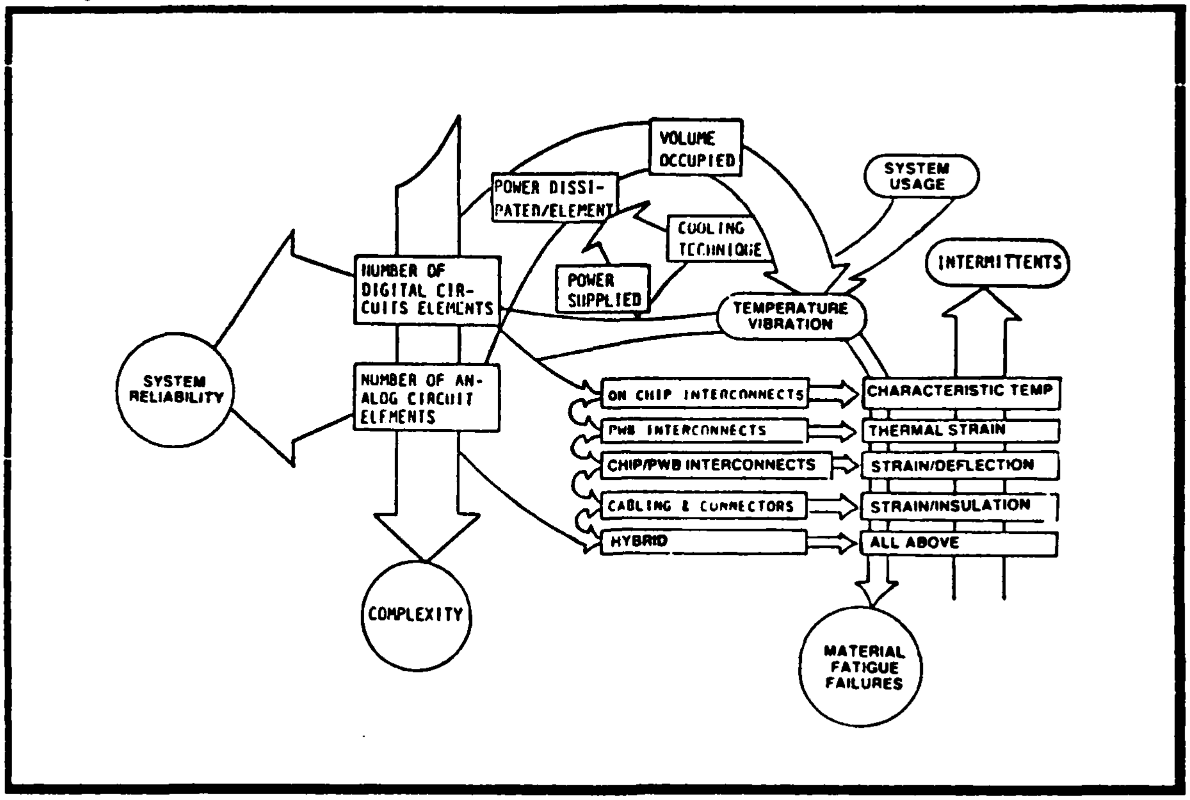
CRACKED KAPTON INSULATION



* TIGHT BENDING RADIUS

#17. Aircraft wiring can also experience fatigue related failure. Shown at the left are cracks in Kapton wire insulation which was stressed at a bend in the wire bundle. The strain/failure relationship at the right clearly shows that the lifetime is extended if the stress is reduced through control of wire bending radius and routing.

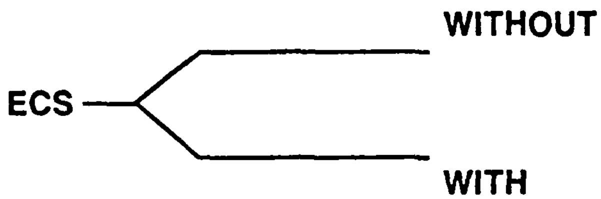
AVIONICS INTEGRITY: SYSTEMS ENG.



#18. The achievement of avionics integrity is truly a systems engineering design problem. The task to be performed drives the selection of a technology which, in turn, dictates the power dissipated by each element. This influences the size of the power supply, the cooling technique to be employed, and the volume needed for the system. Usage dictates the environment in which the system must live and sets the stage for fatigue failure of the materials. The system designer must optimize this synergistic puzzle to achieve performance and lifetime at an acceptable life cycle cost. As we have discussed, integrity is influenced by on-chip interconnections, interconnections to the printed wiring board, cabling and connectors, and selection of hybrids to name a few. Inattention to the design detail at these interfaces can lead to intermittents or fatigue failures all of which reduce the system lifetime.

DESIGN TO USAGE

- **PREDICTABLE LIFE CHARACTERISTICS REQUIRES UNDERSTANDING DESIGN USAGE**
  - **IN-FLIGHT**
  - **ENVIRONMENTAL CONTROL SYSTEM (ECS) MALFUNCTION**
  - **GROUND MAINTENANCE**

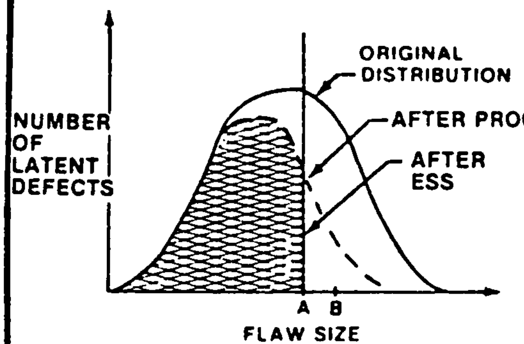


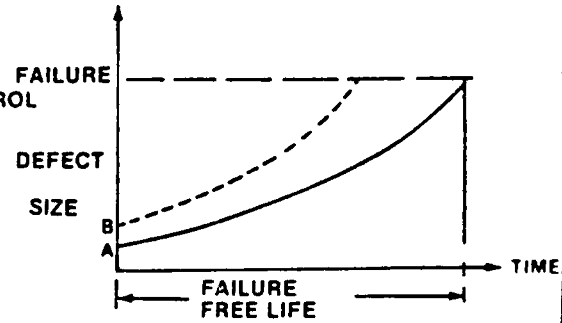
  - **SHOP REPLACEABLE UNIT REPAIR (RESOLDER)**
- **DATA BASE REQUIRED: THERMAL, VIBRATION, POWER QUALITY, ON-TIME "ENVIRONMENT-TIME SENSOR"**

#19. The physical fatigue processes in avionics systems are predictable and controllable. In order to predict the system life characteristics, we must have a detailed understanding of the design usage. This understanding must not only include the in-flight environment, but also the ground maintainance environment. This includes the effect of operating without the prescribed cooling supply. We must understand the effect of repair operations on lifetime. We have seen, for example, the effect of soldering temperatures on the lifetime of electrodeposited copper. We must build a knowledge base for each application to track environmental changes as we change missions. We then can predict the effect of such changes on lifetime.

CONSERVATIVE DESIGN REDUCES FIELD FAILURES

- FATIGUE FRACTURE BASED DESIGN





- CHARACTERIZE MANUFACTURING QUALITY
- DESIGN FOR THERMAL AND MECHANICAL STRESS
- CONTROL MFG, PROCESSES; B
- ELIMINATE DEFECTS ABOVE A GIVEN SIZE (ENVIROMENTAL STRESS SCREEN)

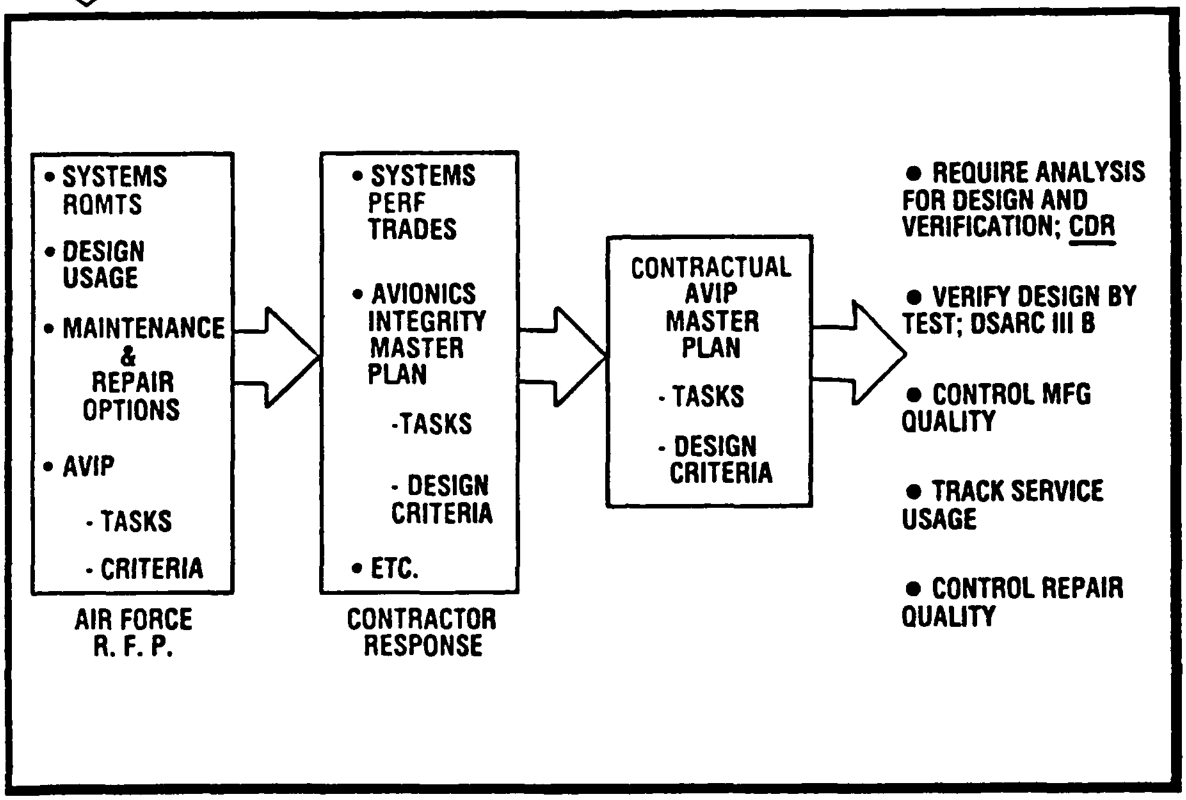
- DEVELOP FATIGUE LIFE MODEL
- ESTABLISH FAILURE FREE LIFE

DESIGN USAGE | MANF. QUALITY | NDI OR ESS (MAX DEFECT SIZE)

- CONTROL REPAIR QUALITY

#20. If we use conservative design practices, the resultant hardware is more tolerant of the stress experienced in the usage environment. Field failures are reduced with a more tolerant design. In any population of components or system subassemblies there is a distribution of defects that can lead to fatigue fracture as we have discussed. Process control can reduce the number and the average size of the defects. We can eliminate defects above a given size and thus assure a minimum failure free lifetime. Eliminating defects above a given size is accomplished through environmental stress screening or non-destructive inspection. With a thorough understanding of design usage, control of manufacturing quality, and elimination of defects above a given size, we can expect a minimum failure free lifetime for the hardware. If we apply the same discipline to our repair process, we can maintain an expected lifetime even after repair.

INTEGRITY PROGRAM: ACQUISITION APPROACH



#21. In implementing our Avionics Integrity Program we have been sensitive to the concerns expressed by industry regarding excessive specifications, tiering of documents, and dictating "how to" design information. Our approach, which utilizes the master plan, is intended as a response to the criticisms. The requirement for AVIP will be included in the Request for Proposal along with the system requirements and design usage. The contractor is expected to respond with a preliminary master plan which includes his tasks and the design criteria to be used with his approach. After the contractor has been selected, the details of the contractual master plan will be worked out to allow a single governing plan to be put on contract. The integrity program emphasizes the importance of analysis for design and verification. The plan will identify the quality control techniques and the methods of verifying the design by test and analysis. The program includes the tracking of in-service usage of avionics and also addresses the need to control repair quality in order to maintain the expected lifetime. We will be emphasizing design verification by analysis at CDR. In addition, we will use the results of the design qualification tests as part of the data base for the production decision.

SUMMARY

- ELECTRONIC SYSTEMS: SMALL SCALE STRUCTURES
  - PREDICTABLE FAILURE CHARACTERISTICS
  - CORROSION CONTROL
  - POWER
- CONSERVATIVE DESIGNS ARE TOLERANT IN MANUFACTURING AND IN THE FIELD
- TECHNOLOGY DRIVING FAILURE LOCATIONS: PARTS TO INTERCONNECTIONS AND BOARDS
- AVIONICS INTEGRITY PROGRAM YIELDS FAILURE FREE MINIMUM FATIGUE LIFE
- PRELIMINARY SPECIFICATION – JULY1984

#22 In summary,

Electrical systems can be considered as small structures subject to the same physical failure processes as large structures.

Conservatively designed systems are tolerant of the stresses induced by manufacturing processes and field usage.

As parts become more reliable under market pressures, we must look to the interconnections of parts and printed wiring boards to achieve the longest lifetime.

The Avionics Integrity Program will provide us with a means of attaining a minumum failure free lifetime.

CONCLUSION

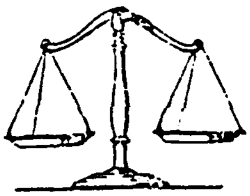
- IMPROVE AVIONICS INTEGRITY -

- APPROACH: DETERMINISTIC PHILOSOPHY
  - DURABILITY
- CONTROL: SERIES OF ACTIVITIES
  - STRESS ANALYSIS
  - DESIGN TO STRESS
- METHOD: MASTER PLAN
  - DESIGN CRITERIA
  - TOOLS

  DESIGN REVIEWS

IMPLEMENTATION STRATEGY

AVIP
DESIGN CRITERIA
TECHNICAL TOOLS



BUSINESS
CONTRACTS, INCENTIVES
& WARRANTIES

#23. The Avionics Integrity Program offers a proven approach to achieve acceptable and cost effective avionics lifetimes. It serves as the technical basis for design reviews. The Avionics Integrity Program compliments business strategies concentrating on incentives and warranties.

Dr. Halpin ended his introductory remarks by introducing an edited videotape of Mr. Dave Steinberg and Mr. John Hagge. Mr. Steinberg's remarks are from a presentation on "Packaging Electronic Equipment for Severe Environments." For additional information, refer to Mr. Steinberg's paper, "Design Guides for Improved Reliability, Proceedings IES, Los Angeles, April 1983." Mr. Hagge's remarks are taken from his presentation on "Reducing Field Fatique Failures in Circuit Board Assemblies." For additional information, refer to Mr. Hagge's paper, "Predicting Fatique Life of Leadless Chip Carriers Using Manson-Coffin Equations," Proceedings IEPS, San Diego, November 1982. The viewgraphs from the videotapes are included here.

PACKAGING ELECTRONIC EQUIPMENT

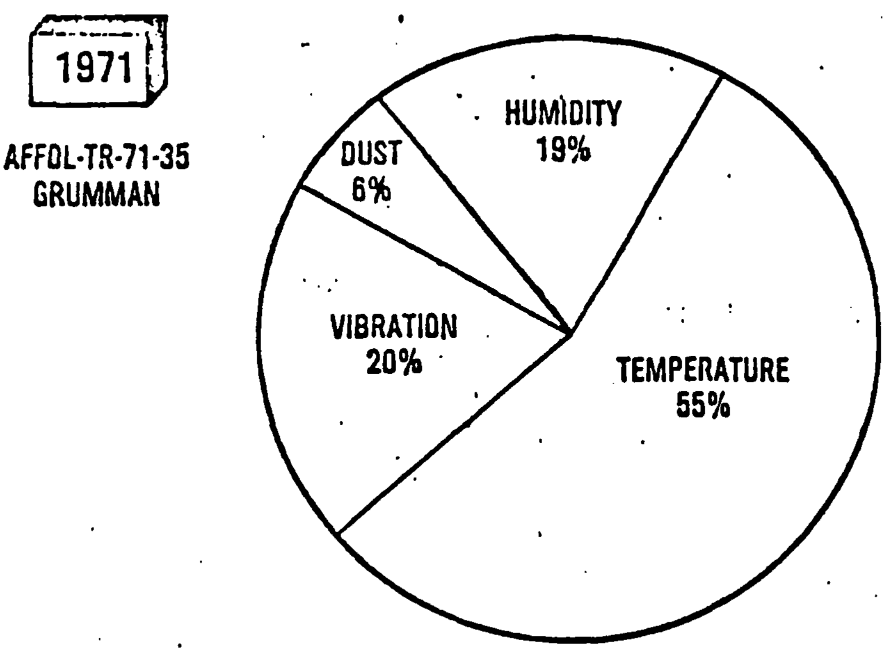
FOR

SEVERE ENVIRONMENTS

by

Dave S. Steinberg

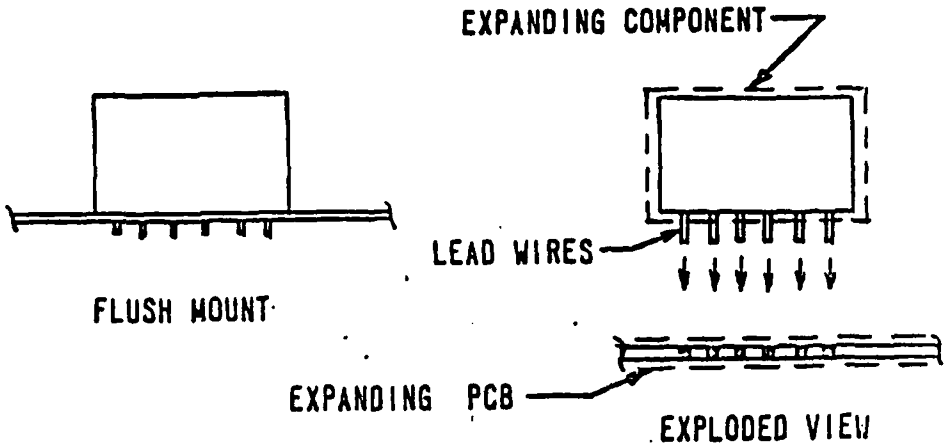
ENVIRONMENTAL INDUCED FAILURES



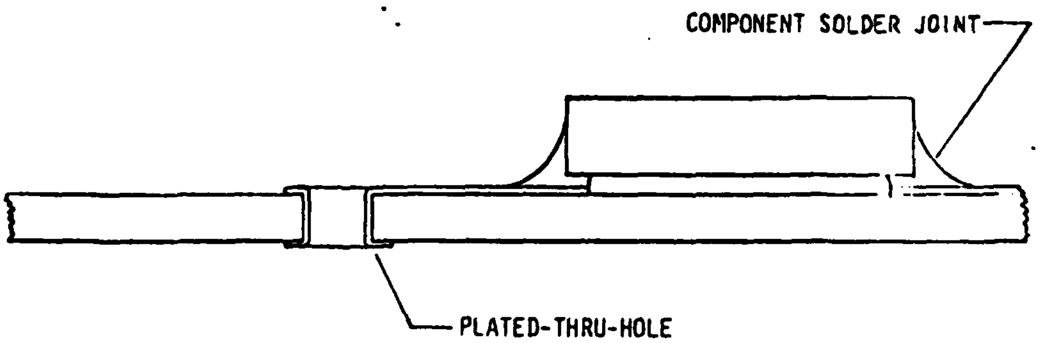
COST TO AIR FORCE - $163 MILLION / YEAR

AVOID FLUSH MOUNTED ELECTRONIC COMPONENTS

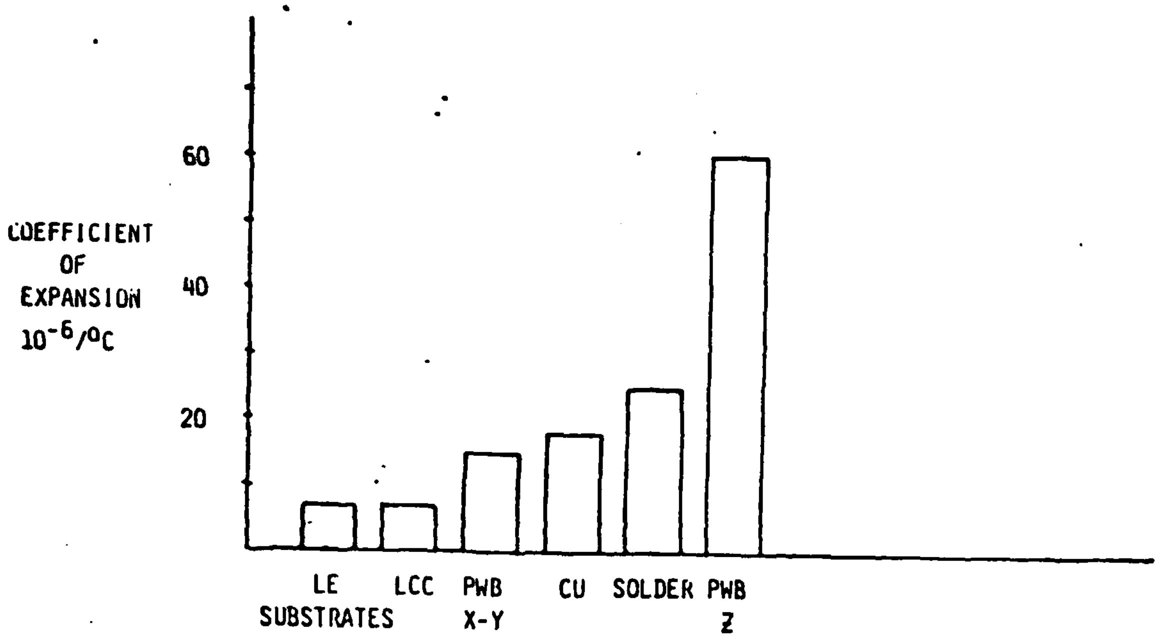
THERMAL EXPANSION GENERATES STRESSES IN SOLDER JOINTS



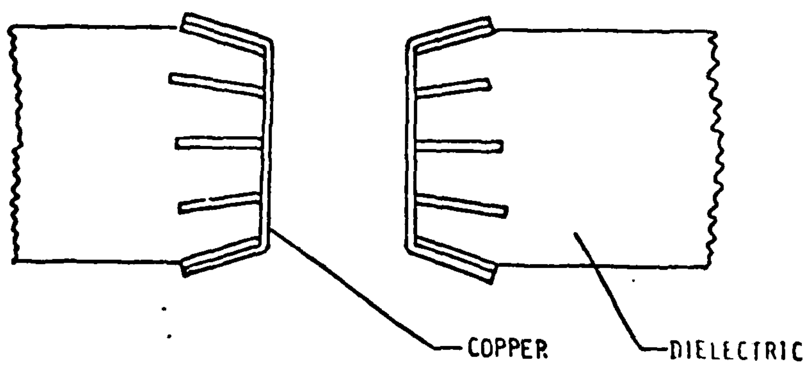
PROBABLI FAILURE LOCATIONS



THERMAL EXPANSION
MISMATCH CAUSES
STRAIN-INDUCED FAILURES

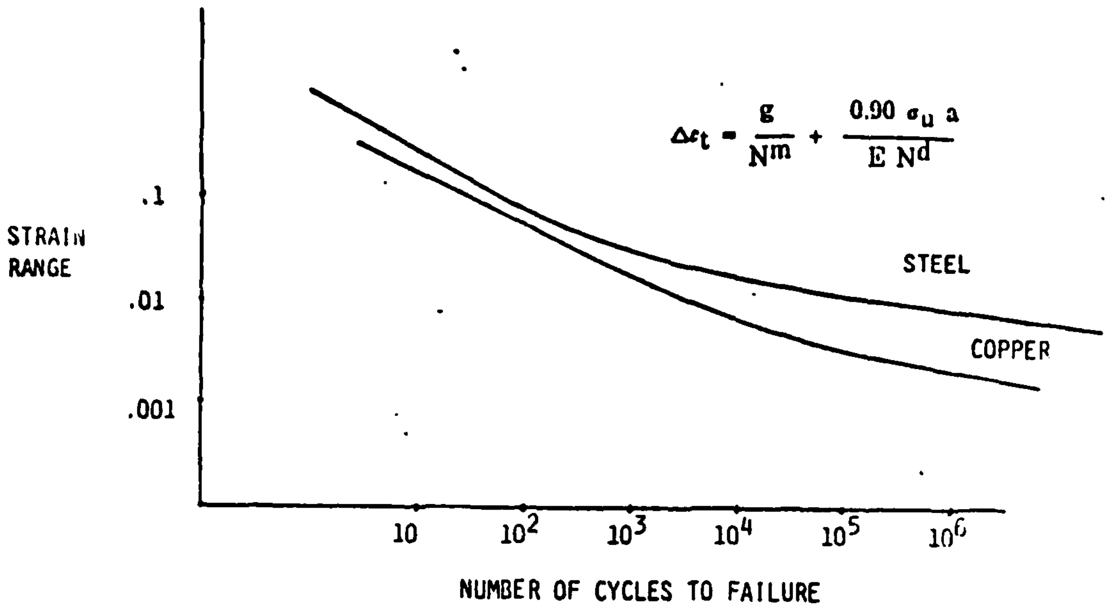


CASE A. PLATED-THRU-HOLE FAILURES

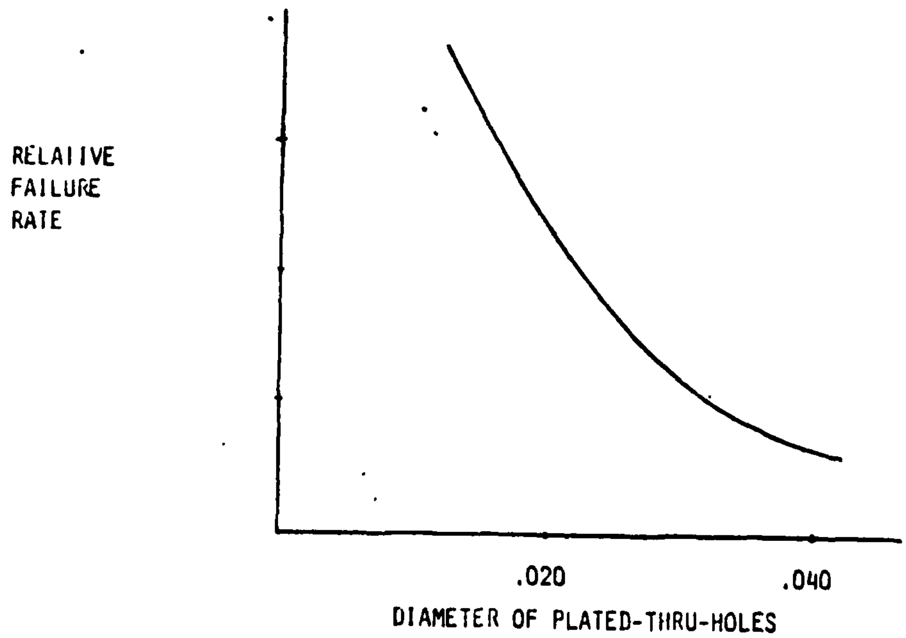


NOTE: THERMAL CYCLING IS STRAIN-CONTROLLED
PROCESS (NOT STRESS-CONTROLLED)

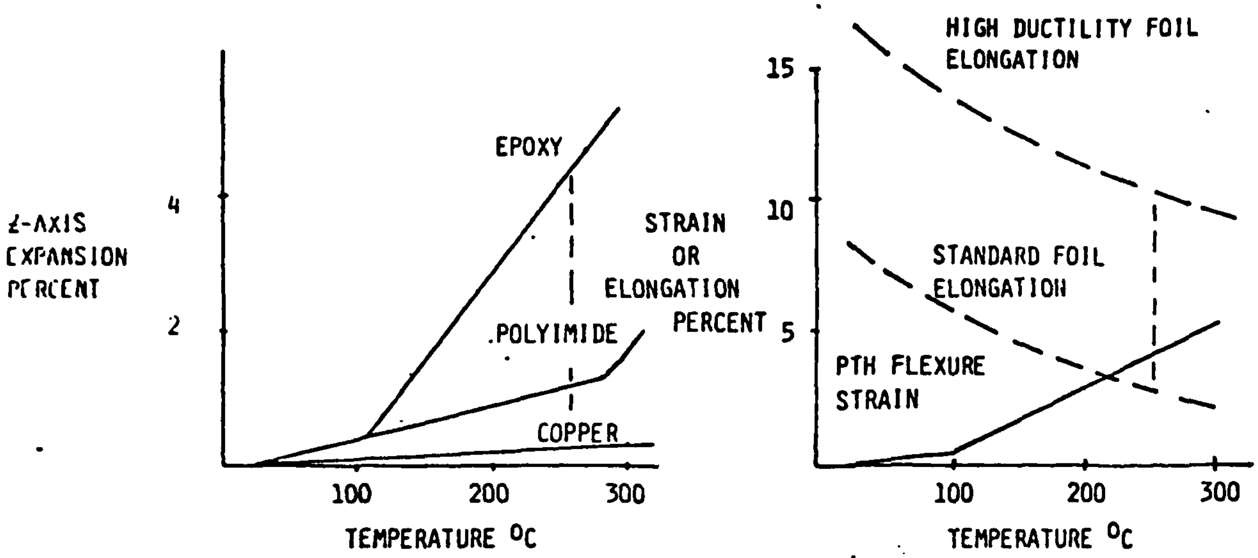
STRAIN-CONTROLLED
FATIGUE EQUATIONS



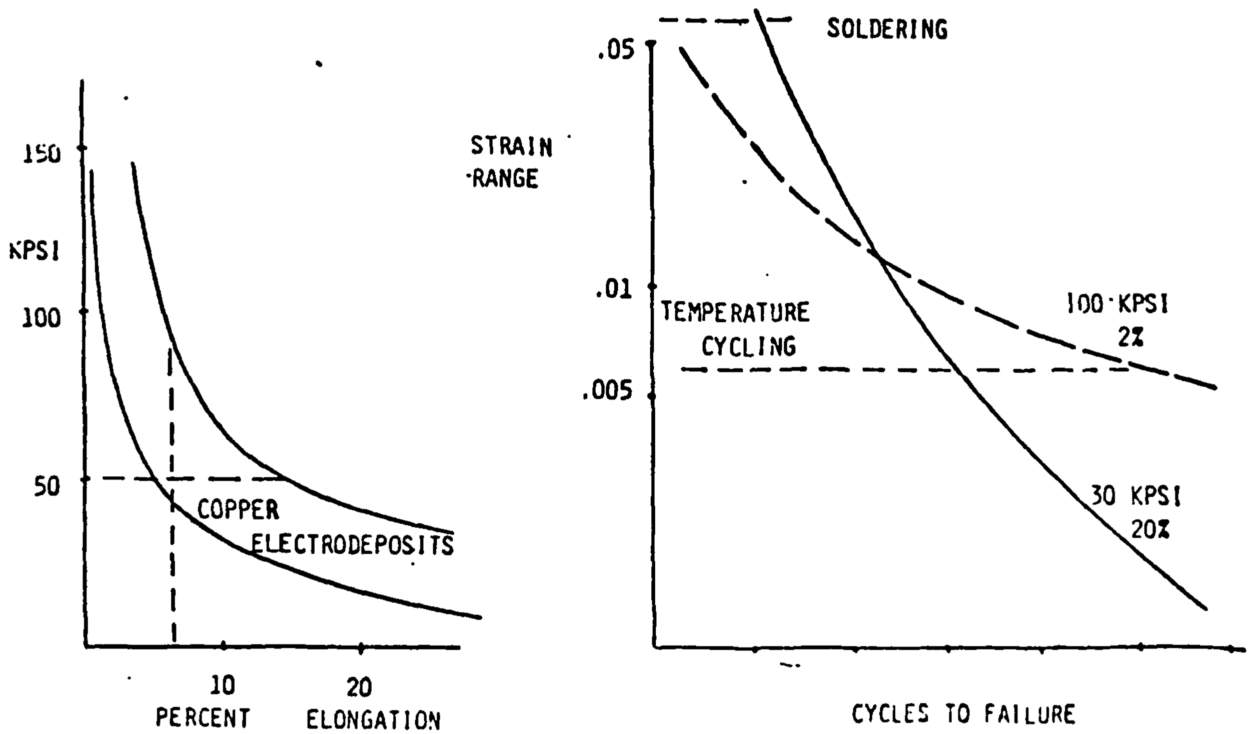
DESIGN PARAMETERS: AVOID OVERSTRAINING SMALL PTH



MATERIALS: USE LOW EXPANSION SUBSTRATES
OR HIGH DUCTILITY COPPER FOILS



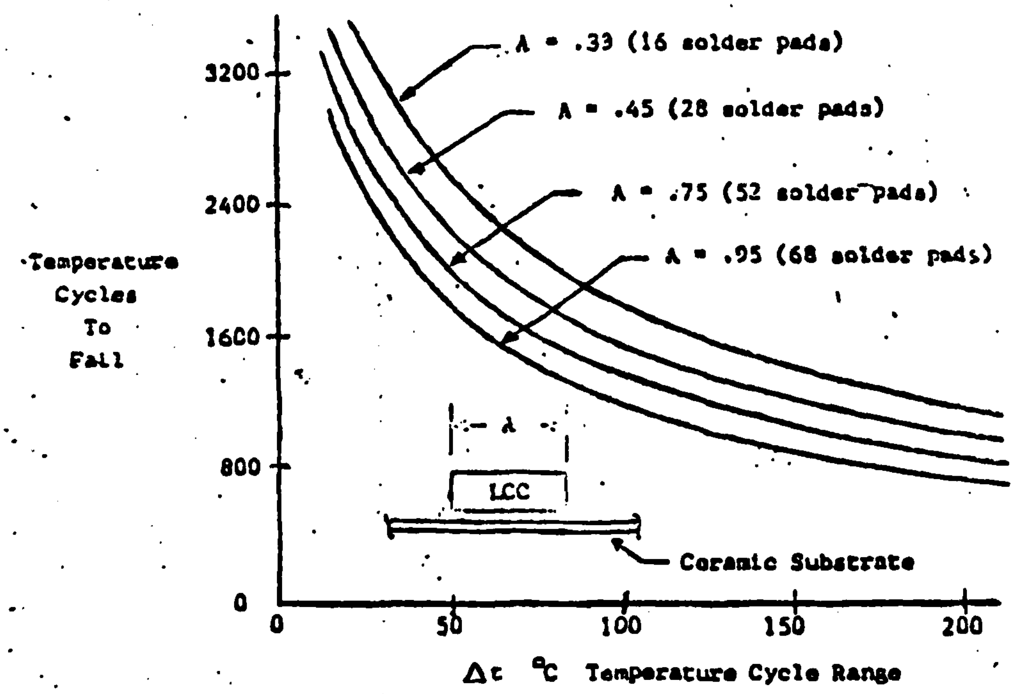
OPTIMIZE PROCESSING: CAREFUL CONTROL
REQUIRED OF PTH ELECTRODEPOSITS



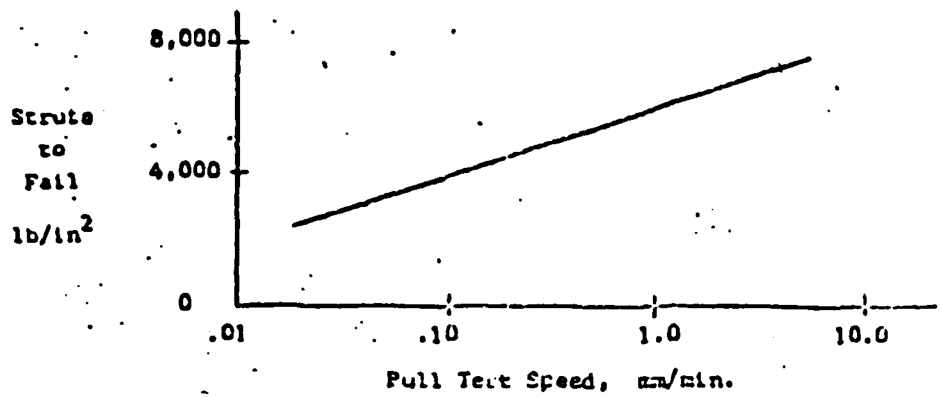
CASE B

FATIGUE LIFE OF SURFACE MOUNTED COMPONENTS

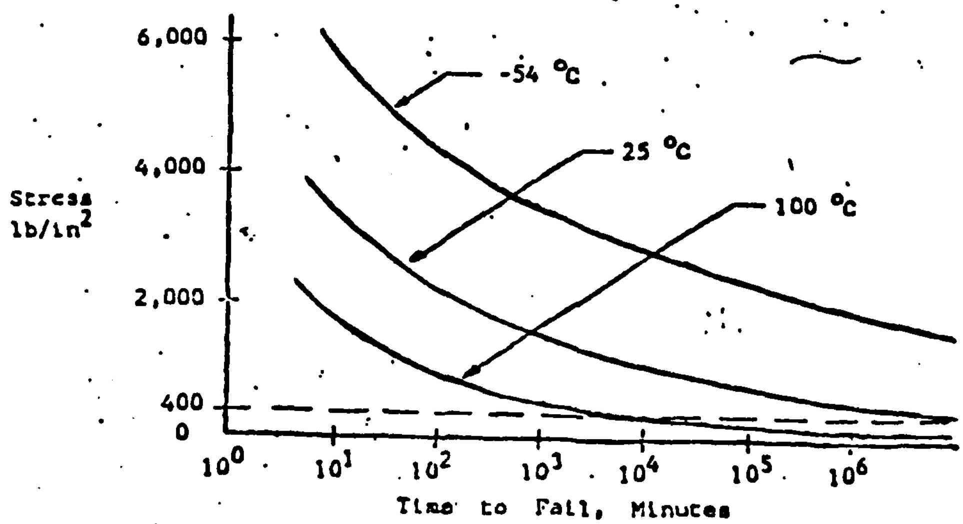
EFFECT OF LCC SIZE VS NUMBER OF TEMPERATURE CYCLES
CREEP SHEAR FAILURE, 63/37 Sn/Pb SOLDER
ZERO POWER DISSIPATION IN LCC



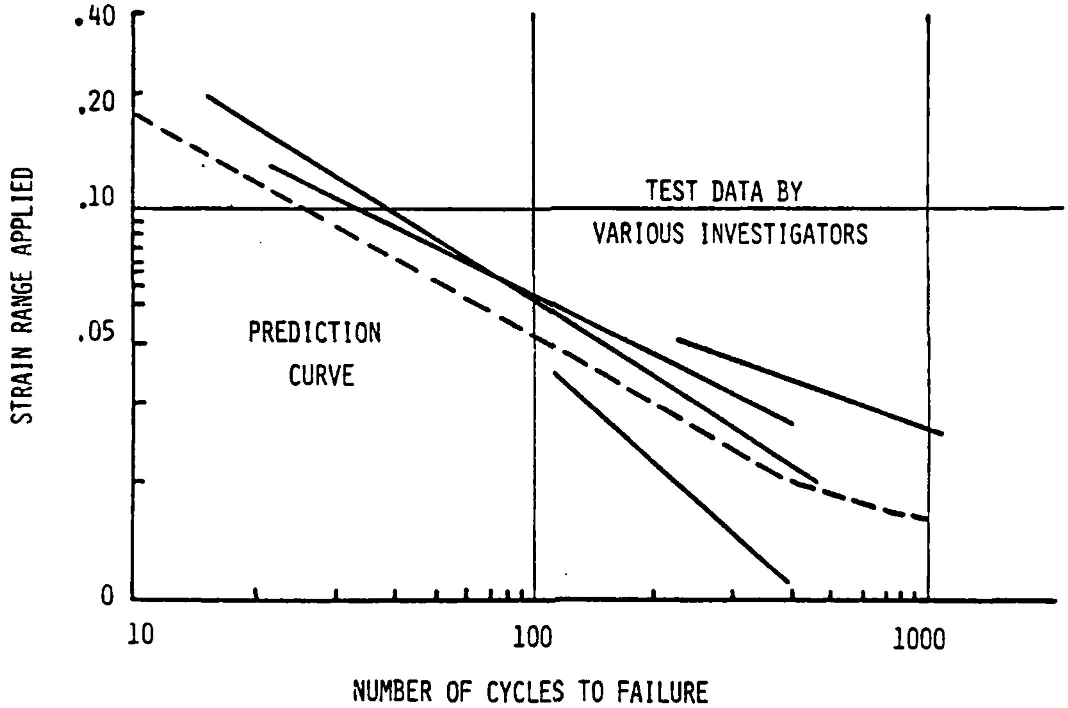
CREEP STRESS TO FAIL
VS
SPEED OF STEADY APPLIED LOAD

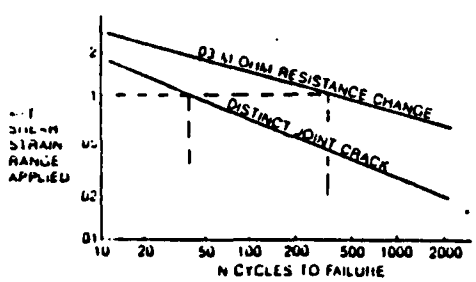


63/37 Sn/Pb SOLDER CREEP STRESS TO FAIL
VS
TIME AND AMBIENT TEMPERATURE

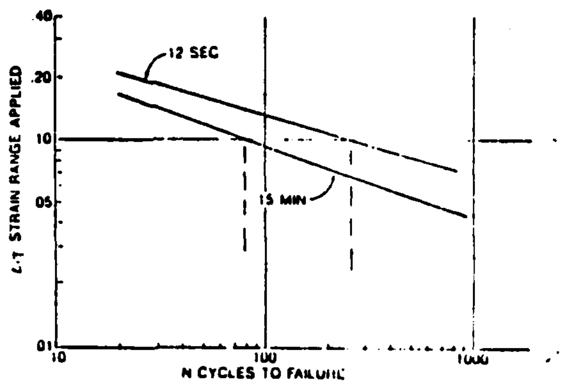


SUCCESSFUL PRODUCTION OF LEADLESS COMPONENT
FATIGUE LIFE WITH MANSON-COFFIN EQUATIONS





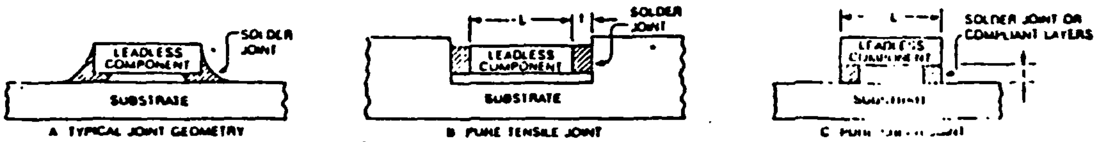
a EFFECT OF FAILURE CRITERION (33)



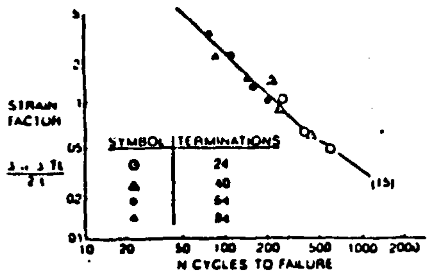
B EFFECT OF CYCLE PERIOD (33)

		TEMPERATURE EXTREMES		DWELL TIME
		LOW	HIGH	
AUTHOR	COMPANY	°C	°C	MIN
Settle	AFAL, WPAFB	-55	+125	0
Jarboe*	BENDIX	-54	+ 75	120
Fennimore	MARTIN MARIETTA	-55	+125	10
Charles & Romenesku	JOHNS HOPKINS	-55	+125	15
Jones	ROCKWELL	-55	+120	30
Love	MARTIN MARIETTA	-40	+ 85	-
Lassen	KOLLMORGEN	-65	+125	30
Fishman & Cooper	ITT	-55	+125	10
Caswell & Isaacson	TRACOR	-55	+125	15

DESIGN PARAMETERS: MINIMIZE L, COMPONENT SIZE;
AND MAXIMIZE t, STAND-OFF HEIGHT

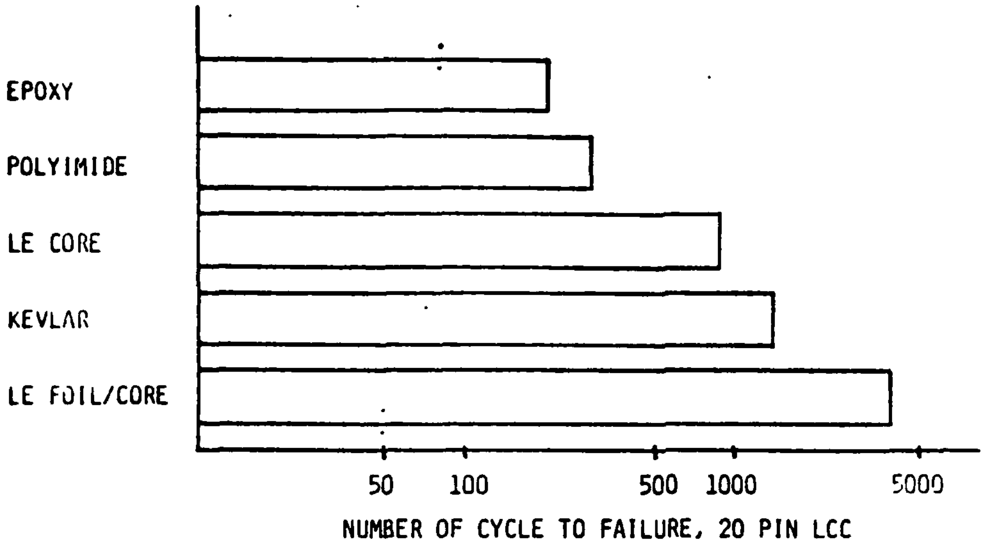


$$\text{Strain} = \frac{\Delta\alpha\Delta TL}{2t}$$

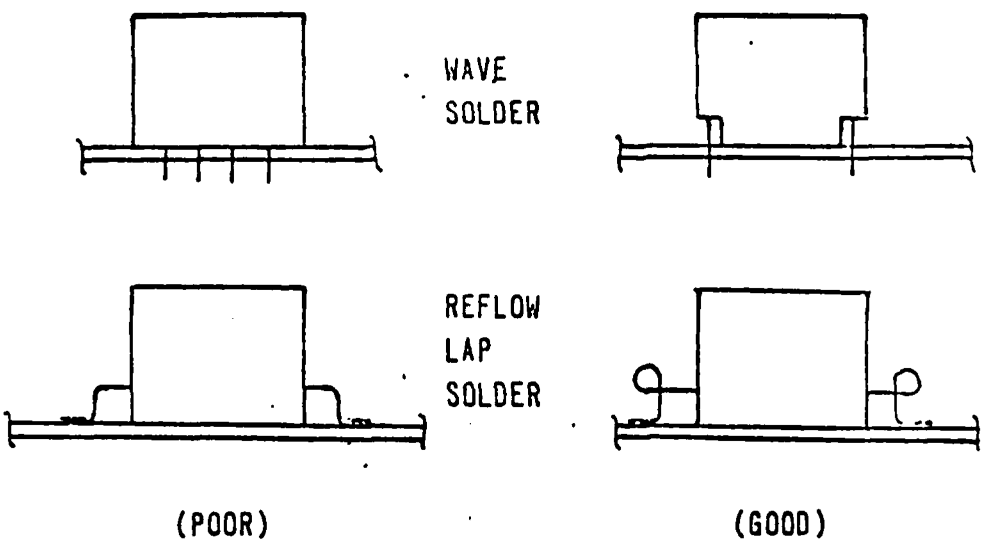


$$\Delta\epsilon_t = \frac{\beta}{N^m} + \frac{0.90\,\sigma_u\,a}{E\,N^d}$$

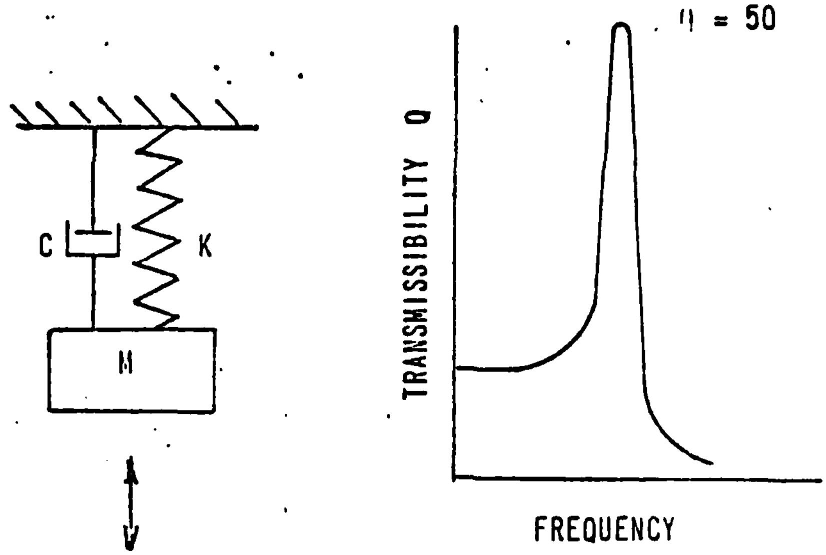
OPTIMIZE MATERIALS CHOICES: USE A SUBSTRATE WHICH MEETS YOUR REQUIREMENTS



MOUNTING TRANSFORMERS



MOST FAILURES ARE DUE TO A SEVERE RESONANT CONDITION

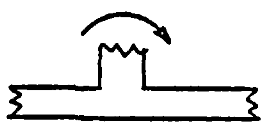


STRESS CONCENTRATIONS

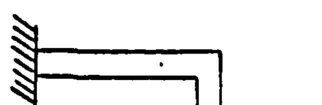
HOLES

NOTCHES

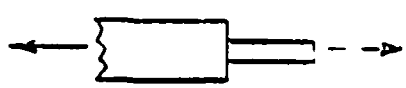
SHARP CORNERS



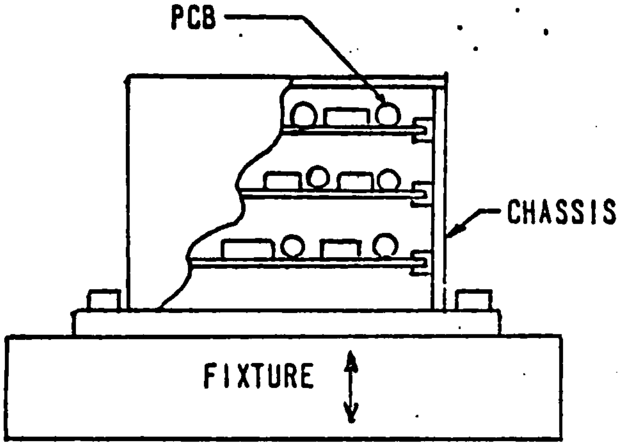
SHARP BENDS

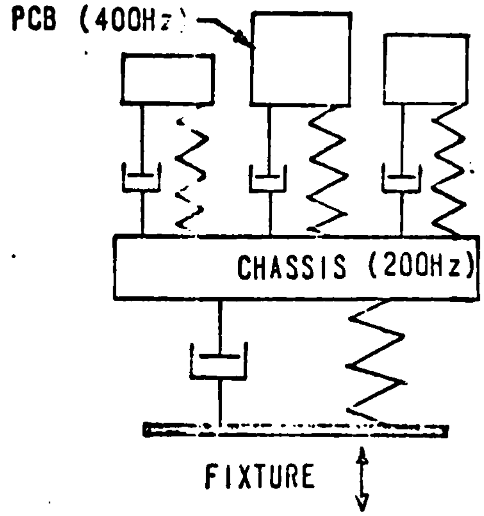


SHARP CHANGES IN
CROSS SECTIONS



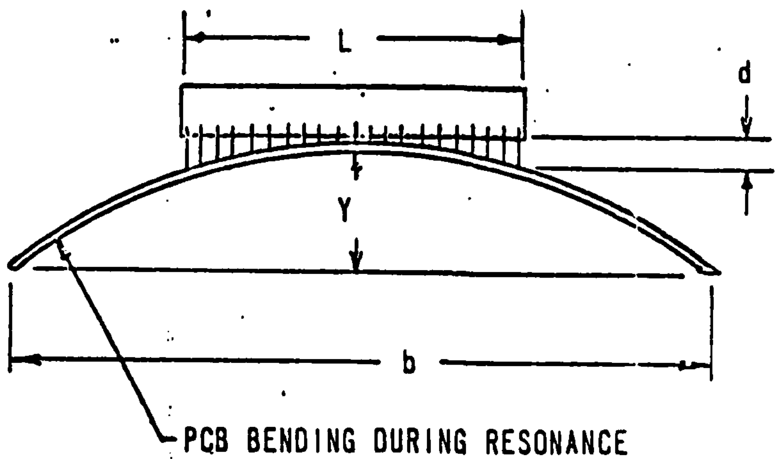
REDUCE FAILURES WITH THE USE OF THE OCTAVE RULE





DOUBLE THE NATURAL FREQUENCY FOR EVERY ADDED DEGREE OF FREEDOM

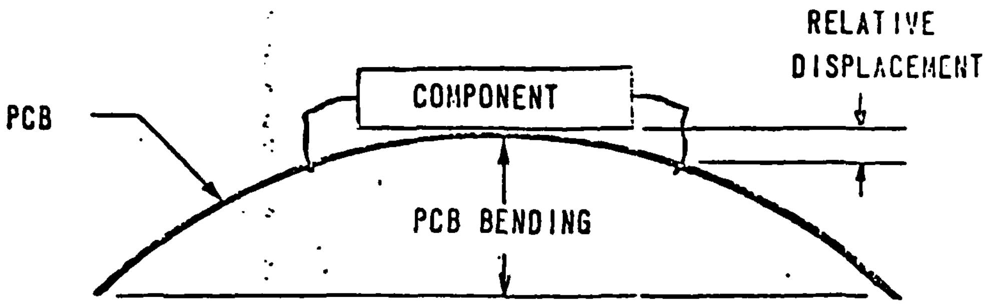
MOUNTING LARGE COMPONENTS



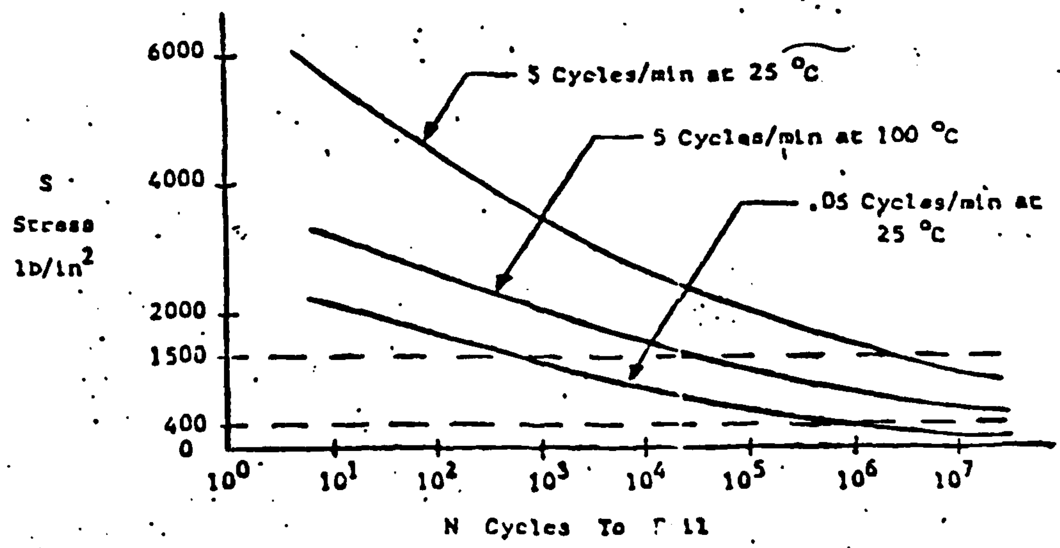
PCB DESIGN

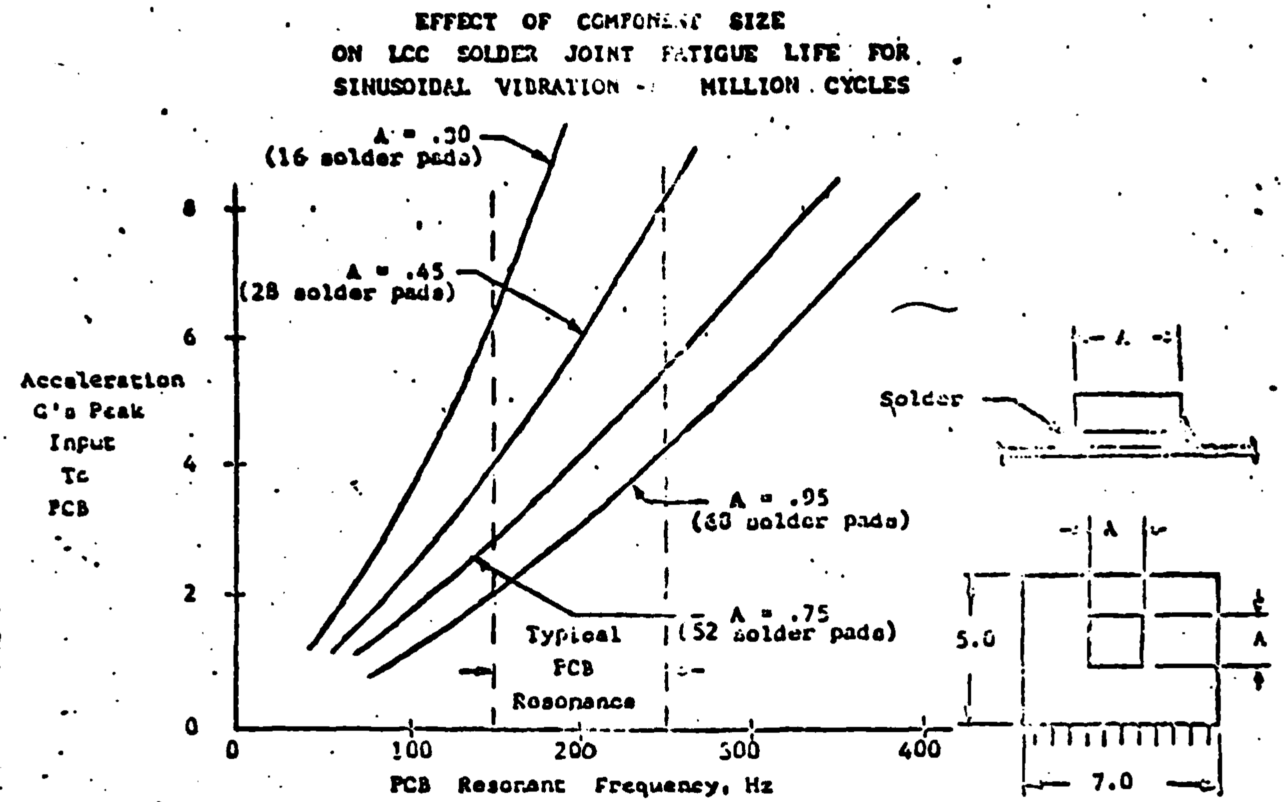
FAILURES OCCUR IN COMPONENT LEAD WIRES AND SOLDER JOINTS

DUE TO LARGE DYNAMIC DISPLACEMENTS, WITH POOR STRAIN RELIEF

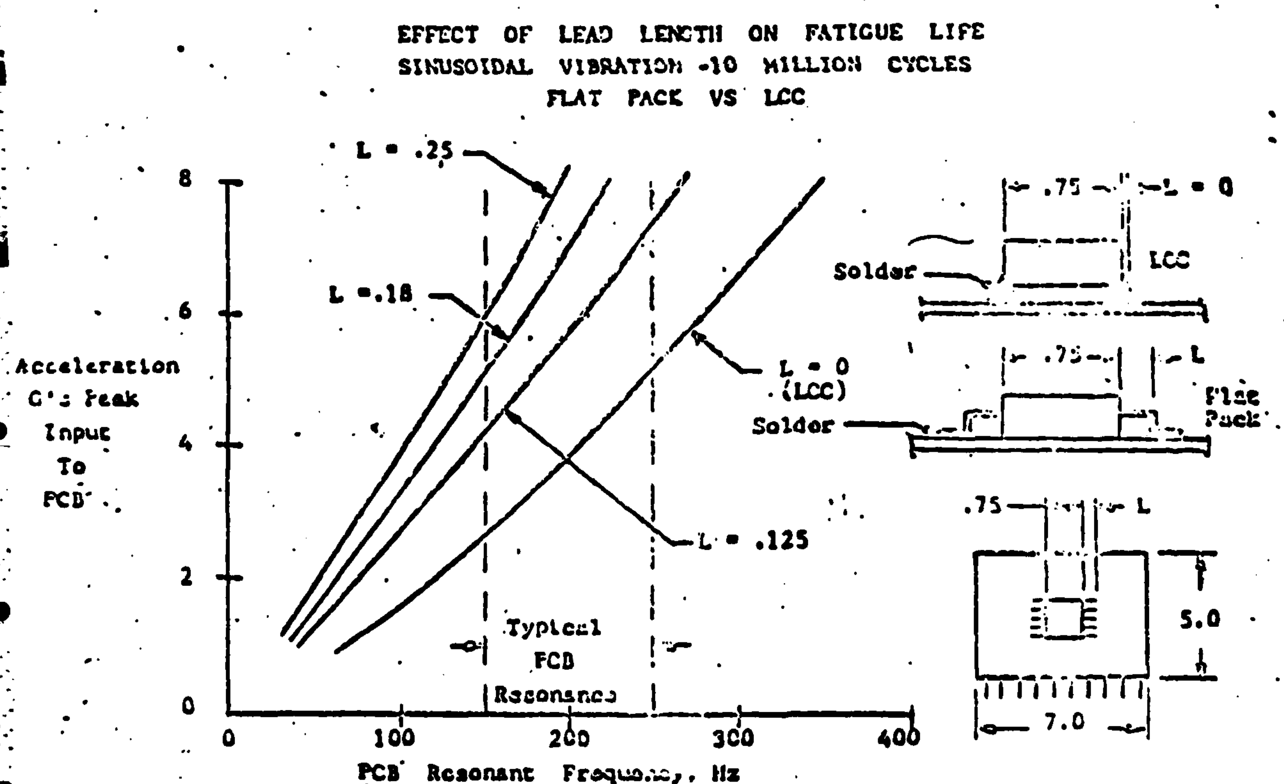


63/37 Sn/Pb SOLDER ALTERNATING LAP SHEAR STRESS
VS
TEMPERATURE AND FREQUENCY OF APPLIED LOAD





EFFECT OF COMPONENT SIZE
ON LCC SOLDER JOINT FATIGUE LIFE FOR
SINUSOIDAL VIBRATION - MILLION CYCLES
A = .30
(16 solder pads)
A = .45
(28 solder pads)
A = .95
(88 solder pads)
A = .75
(52 solder pads)
Typical
PCB
Resonance
Acceleration
G's Peak
Input
To
PCB
PCB Resonant Frequency, Hz
Solder
A
5.0
7.0



EFFECT OF LEAD LENGTH ON FATIGUE LIFE
SINUSOIDAL VIBRATION -10 MILLION CYCLES
FLAT PACK VS LCC
L = .25
L =.18
L = 0
(LCC)
L = .125
Typical
PCB
Resonance
Acceleration
G's Peak
Input
To
PCB
PCB Resonant Frequency, Hz
.75
L = 0
Solder
LCC
L
Flat
Pack
5.0
7.0

SUMMARY

1. TEMPERATURE DEFORMATION OF PTH IS ELASTIC UP TO 80°C, PLASTIC ABOVE 80°C

2. PTH COPPER SHOULD BE ABOVE 6% ELONGATION, 50KPSI

3. PTH LIFE IS INCREASED WITH LARGER PTH AND POLYIMIDE PWB'S

4. SOLDER JOINT DEFORMATION IS PREDOMINANTLY PLASTIC, THEREFORE HIGH SOLDER DUCTILITY IS IMPORTANT
   - AVOID SOLDER CONTAMINANTS
   - AVOID HOT STORAGE OR SLOW COOLDOWN

SUMMARY (CONT)

5. FATIGUE LIFE DECREASES WITH
   - LARGER COMPONENTS
   - THIN SOLDER JOINTS
   - LARGE TEMPERATURE EXTREMES
   - LARGE COEFFICIENT OF EXPANSION MISMATCH

6. MANSON-COFFIN ANALYSES ARE USEFUL TOOLS FOR
   - GUIDING PRODUCT/PRODUCTION DESIGN
   - PREDICTING CYCLES TO FAILURE

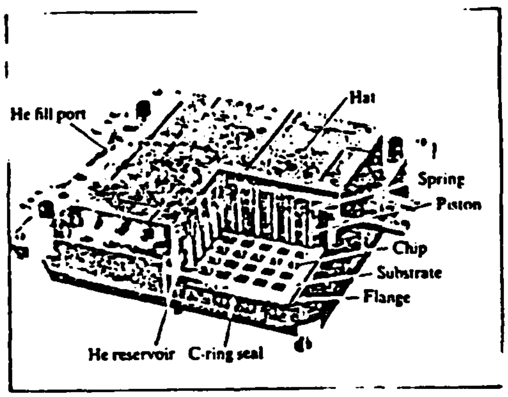
The first speaker, Dr. Ajay Sharma, discussed the details of why IBM's Thermal Control Module has a very high reliability. Here are the viewgraphs of his presentation.

THERMAL CONTROL OF LSI MODULES

IN

IBM 3081 COMPUTERS

A. Sharma
IBM, General Technology Division
East Fishkill, NY



The Thermal Conduction Module (TCM)

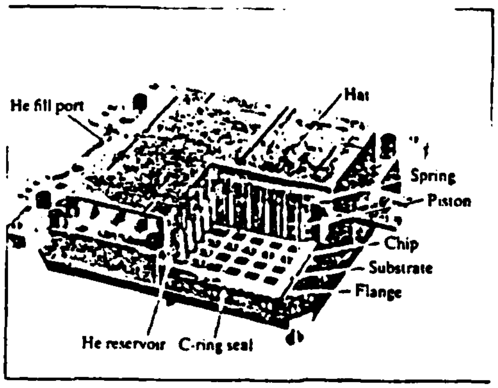
- Multi-layer ceramic substrate
- Upto 118 LSI chips
- 250M circuits per cubic meter
- Upto 4W per chip, 300W per module
- Mechanical, thermal and environmental encapsulation

Product Requirements

- Wide range of environmental conditions
- Cooling water between 22 and 31C
- Chip powers vary between 0.4 and 2.7W (Nominal), design maxima 4W.
- Chip temperatures maintained: 40 – 85C
- Chip to water thermal resist. ≦ 13C/W
- Repairing capability
- Field-replaceable unit

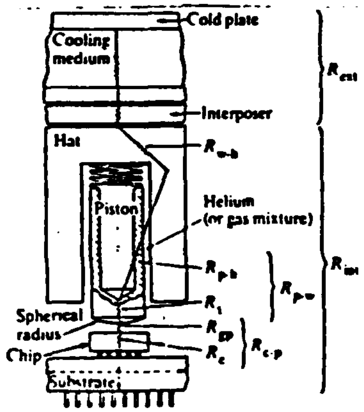
DESCRIPTION

- Cold Plate
  BeCu water cooled heat sink
  Screw attachment to hat
  0.02 C/W water to hat
- Hat Assembly
  Described in detail on next slide
- Interposer
  Allows upward temperature adjustment
- C-ring
  Lead-plated Inconel, caoted with wax
  Provides reworkable, hermetic seal
- Substrate
  MLC, 90×90 mm, upto 33 layers,
  1800 I/O pins



Hat Assembly

- Contains a piston for each chip
- Aluminum alloy pistons with crowns
- Accomodates chip and piston tilts
- Filled with helium to enhance thermal interfaces
- End of life air ingress of 13%
- Seals tested to 3600 cycles of 25–75C
- Thermal resistance: 8.4 to 9.1 C/W



Cooling Development

- Chip to piston resistance:
  Pressure, chip tilt, piston crown
- He vs. Air: 7.9 C/W vs. 22 C/W
- Limit air ingress to 13 percent
- Three dimensional thermal models
- Interposers added to maintain 40 – 85C
- Special thermal test vehicles
- Stress tests: vibration, shock, on/off

Conclusions

- Cooling capability for 25000 logic circuits and 65000 array bits per module of 0.001 cubic–meter volume
- Very high reliability
- Extendable cooling capacity
- High heat fluxes (100 KW per square m)
- Hermetic enclosure isolates from external environment

Reference

S. Oktay and H.C. Kammerer,

"A Conduction–Cooled Module for High–
Performance LSI Devices,"

IBM Journal of Research and Development,

Volume 26, Number 1,
January 1982.

The next speaker was Mr. John Devaney from Hi Rel Laboratories. The following is a summary of Mr. Devaney's remarks:

In failure analysis as elsewhere this famous quote is very relevant. "Those who are ignorant of history are doomed to repeat it."

In failure analysis we are still analyzing the same failures we were over 20 years ago. Prior to about 1967 we felt that if they were properly built, semiconductors would not wear out. Since then we have started talking about wearout mechanisms in semiconductors and we have found that thermal cycling or thermal stressing is one of the key factors in aggravating failures. Some other failure mechanisms are intermettalics (purple plague failure and bonding), corrosion, electromigration, dendrite growth, nodule formation and ionic leakage paths.

There are several types of failure analysis (or as some people call it -- process control or process engineering). First of all we have environmental stress test screening which was done extensively on the Minuteman missile. Greater and greater stresses were applied to the part until it failed and then analyzing the failures to determine the root cause failure mechanism and then either redesigning the component or its application in the system. The other type of failure analysis is the analysis of the part when it fails in the system.

For failure analysis to be effective a number of factors are of major concern: the turnaround time (need answers in hours or days usually), cost, creditabilty.

The future of failure analysis, as integrated circuits get smaller and more complex, depends upon power, temperature cycling and the mechanisms that are no longer screenable by brute force, i.e. how do we think about what the potential problems might be without waiting for failures to occur in the field.

It is more and more important for the manufacturer and the user to work as a team. We need to do less assessing of blame, less "finger-pointing" and more "what can we do to fix it."

Most of what we know has already been published, but most of the time failure analysts call each other to find out if someone else has seen the failure mode which they themselves don't recognize. Usually under the time constraints of failure analysis, we are not willing to look through the books and papers to find the answer to our problem. Our base problem then is that people don't recognize failure modes. There are very few comprehensive studies on failure analysis with photo atlases to show what the failure mode looks like and then to describe its root cause.

Mr. Devaney then showed some slides of actual failure modes.

The next speaker, Col Dalton Wirtenan, also discussed the government's use of stress screening from the DESC/E point of view. Col Wirtenan's viewgraphs are included here.

D E S C

DoD INVENTORY MANAGER FOR 800,000 PARTS

PROVIDE COMPONENT ENGINEERING TO THE MILITARY

- PREPARE OVER 1200 STANDARDIZATION PROJECTS EACH YEAR
- MAINTAIN AND DEVELOP SOURCES FOR QPLs
- AUDIT VENDORS
- MANAGE DESC TEST FACILITY
- PROVIDE COMPONENT APPLICATION INFORMATION/PARTS CONTROL
- PROVIDE DCAS TECHNICAL TRAINING

D E S C

ESS OF COMPONENTS CAN IMPROVE PERFORMANCE/RELIABILITY OF SYSTEMS/EQUIPMENT

HI-REL MIL PARTS PROVIDE ESS

- MIL-STD-833 (MICROCIRCUITS) AND MIL-STD-750 (SEMICONDUCTORS)

DESC TEST FACILITY RESULTS SHOWS THE SCREENING EMPHASIS SHOULD BE ON COMMERCIAL PARTS

LOGISTICS EXPLOSION W/O STANDARDIZATION

- DESC ESTIMATES POSSIBLE TRIPLING OF OUR INVENTORY WITHIN 3 YEARS W/O STANDARDIZATION

D E S C

MIL-STD-883 100 % SCREENING (CLASS B MICROCIRCUITS)

- INTERNAL VISUAL:
- STABILIZATION BAKE: 24 HRS. @150°C
- TEMPERATURE CYCLING: -65°C TO +150°C; 10 CYCLES
- ACCELERATION: 30,000G, Y 1 ORIENTATION
- BURN-IN: 160 HRS. @ +125°C
- FINAL ELECTRICALS: STATIC @ -55°C, 25°C, 125°C
  FUNCTIONING @ 25°C
  SWITCHING @ 25°C
- SEAL TEST: FINE AND GROSS
- EXTERNAL VISUAL

D E S C

JAN BRANDING POLICY

INSPECTIONS AND TESTS TO VERIFY COMPLIANCE WITH THE SPEC DOES NOT JEOPARDIZE THE JAN BRAND

SELECTING PARTS TO TIGHTENED ELECTRICAL PARAMETERS DOES REQUIRE AN NSP (CONTRACTOR DRAWING)

DESC

INSPECTION AND SCREENING OF ALL COMPONENT PARTS LEADS TO INCREASED ELECTRONICS INTEGRITY

ESS REQUIREMENTS MUST BE CARRIED THROUGH THE LOGISTICS SYSTEM

PARTS STANDARDIZATION + APPROPRIATE SCREENING = INCREASED SYSTEM READINESS

- USE OF HI-REL MIL PARTS = COST EFFECTIVE APPROACH TO ESS
- ALL COMMERCIAL PARTS DOCUMENTATION SHOULD INCLUDE REQUIREMENTS FOR INCOMING INSPECTION AND ESS

USE OF DoD DOCUMENTATION TO PROVIDE "STANDARDIZED COMMERCIAL PARTS AND SCREENING"

The next speaker, Mr. Ed Koenig from Warner Robbins ALC discussed the "Use of Stress Screening At the Depot." His briefing viewgraphs are included here.

ELECTRONIC COMPONENT

SCREENING BRIEFING

FOR

NAECON '84

ELECTRONIC COMPONENT SCREENING

* A WARNER ROBINS ALC INITIATIVE AIMED AT IMPROVING THE QUALITY OF REPAIRED AVIONICS PROVIDED TO USING COMMANDS

* A COMPREHENSIVE PROCESS TO ELECTRICALLY TEST AND ENVIRONMENTALLY STRESS COMMON ELECTRONIC COMPONENTS PRIOR TO THEIR UTILIZATION IN THE REPAIR OF AIRBORNE ELECTRONICS EQUIPMENT.

COMPONENTS SCREENED

* COMMON VARIETY ELECTRONIC COMPONENTS REPRESENTING THE HIGHEST USAGE NSNs FOR THE DIVISION

STOCK CLASS	TYPE OF COMPONENT
5905	RESISTORS
5910	CAPACITORS
5961	TRANSISTORS & DIODES
5962	INTEGRATED CIRCUITS

BRIEFING TOPICS

* WHY ECS IS NEEDED
  - FACTORS AFFECTING QUALITY OF RECEIVED COMPONENTS
  - IMPACT OF SUBSTANDARD PARTS ON AVIONICS REPAIR
* THE ECS PROCESS
* WHAT ECS ACCOMPLISHES

SOURCE OF SUPPLY

* THE VAST MAJORITY OF ELECTRONIC COMPONENTS UTILIZED BY WR-ALC/MAI FOR REPAIR ACTIVITIES ARE SUPPLIED BY THE DEFENSE LOGISTICS AGENCY (DLA) THROUGH THE DEFENSE ELECTRONICS SUPPLY CENTER (DESC)

* WR-ALC'S REQUIREMENTS ARE INTEGRATED WITH THOSE OF OTHER DOD ACTIVITIES, RESULTING IN BULK ACQUISITION OF NEEDED COMPONENTS BY THE DLA TO MEET HUGE DEMAND LEVELS

COMPONENT PROCUREMENT

* PARTS ARE OBTAINED UNDER THE TIME-HONORED PROCUREMENT PRACTICE OF CONTRACTING FOR REQUIRED MATERIAL FROM THE LOWEST QUALIFIED BIDDER.

* A PREMIUM IS PAID FOR 100% QUALITY ASSURANCE LEVEL COMPONENTS (IT IS COST-PROHIBITIVE TO PROCURE SUCH PARTS ACROSS-THE-BOARD)

* ANY ONE "QUALIFIED" SUPPLIER POSSESSING PARTS WHICH MEET PROCUREMENT REQUIREMENTS CAN BID FOR CONTRACT:

  - COMPONENT MANUFACTURERS
  - PARTS DISTRIBUTORS
  - "GARAGE" OPERATIONS

NATURE OF PROCURED PARTS

* WIDE VARIANCE IN PARTS QUALITY ASSURANCE LEVEL
* SMALL LOTS OF COMPONENTS OF THE SAME NSN WILL CONTAIN PARTS FROM SEVERAL SUPPLIERS
* DUE TO COMPONENT STOCKPILING BY DLA, THE AGE OF SUPPLIED COMPONENTS VARIES WIDELY (MAI HAS RECEIVED COMPONENTS MANUFACTURED AS EARLY AS 1956).

DESC TEST EFFORTS

* RECOGNITION OF THE VARIANCES IN PARTS QUALITY PROMPTED DESC TO ESTABLISH A SAMPLE TEST CAPABILITY IN THE LATE 1970'S
* DUE TO DESC'S LIMITED CAPABILITIES, ONLY 40% OF ONE FEDERAL STOCK CLASS (FSC 5961) ARE CURRENTLY SUBJECTED TO SAMPLE TESTING
* DESC HAS PLANS TO UPGRADE THE NUMBER AND TYPES OF COMPONENTS SAMPLE TESTED DURING THIS DECADE

DESC TEST METHODOLOGY

* DESC REVIEWS ALL PARTS PROCUREMENT CONTRACTS AND SELECTS APPROXIMATELY 40% TO UNDERGO SAMPLE TESTING

* THE DLA WAREHOUSE IS NOTIFIED AND SHIPS A SMALL SAMPLE FROM SELECTED INCOMING LOTS TO THE TEST LABS

* AT DESC, THE SAMPLE IS ELECTRICALLY TESTED. IF ANY FAILURES ARE ENCOUNTERED, A LARGER SAMPLE IS FORWARDED FOR TEST. BASED ON TEST RESULTS, STANDARD STATISTICAL CRITERIA ARE UTILIZED TO ACCEPT OR REJECT THE LOT BASED ON THE NUMBER OF FAILURES.

* IF LESS THAN A STATISTICALLY DETERMINED NUMBER FAIL, THE LOT IS ORDERED INTO WAREHOUSE STOCK FOR DISTRIBUTION.

OTHER NEGATIVE FACTORS

* MAJOR COMPONENT MANUFACTURERS PURSUING MARKET FOR CONSUMER ELECTRONICS RATHER THAN MILITARY CONTRACTS. LESSER FIRMS TAKE UP THE SLACK.

* CHANGES IN MANUFACTURING SITES OFTEN ADVERSELY AFFECTS COMPONENT PERFORMANCE LEVELS.

IMPACT OF SUBSTANDARD MATERIAL

* SUBSTANDARD OR DEFECTIVE PARTS UTILIZED IN DEPOT REPAIR PROCEDURES NECESSITATE EXPENSIVE REWORK OF ASSEMBLIES

  - TROUBLESHOOTING
  - REMOVAL/REPLACEMENT
  - RETESTING
  - POTENTIAL DAMAGES/QUALITY PROBLEMS FROM EXTRA REWORK

* INFANT MORTALITY COMPONENTS RESULT IN EARLY FIELD FAILURES - UNNECESSARY REPAIR CYCLES

IMPLEMENTATION PLAN

* SUBJECT 100% OF HIGH USAGE COMPONENTS TO SCREENING PROCESS

* ELECTRICALLY TEST AGAINST COMPONENT SPECIFICATION

* ENVIRONMENTALLY STRESS TO WEED OUT UNSTABLE COMPONENTS (INCLUDING INFANT MORTALITY FAILURES)

* PROVIDE 100% GOOD BENCH STOCK FOR AVIONICS REPAIR WORK

ECS PROCESS

* DEPENDING ON COMPONENT TYPE, A COMBINATION OF THE FOLLOWING MIL-STD-750C OR MIL-STD-883B TESTS ARE CONDUCTED:

VISUAL INSPECTION	CONSTANT ACCELERATION
HERMETIC SEAL	HIGH TEMP REVERSE BIAS
STABILIZATION BAKE	THERMAL SHOCK
TEMPERATURE CYCLING	BURN-IN

"GROUP A" ELECTRICAL TESTS - UP TO 3 TIMES DEPENDING ON ENVIRONMENTAL TEST PROGRAM

* 150,000 TO 200,000 COMPONENTS SCREENED/YEAR

ESC RESULTS

* COST AVOIDANCE BENEFITS COMPUTED IN FY82 FOR REMOVING INCOMING SUBSTANDARD AND INFANT MORTALITY COMPONENTS WERE $43.70 AND $814.27 PER PART, RESPECTIVELY.

* BASED ON A CONSISTENTLY DEMONSTRATED FAILURE OF LEVEL OF APPROXIMATELY 4%, YEARLY BENEFITS EXCEED ECS FACILITY START-UP AND OPERATING COSTS BY BETTER THAN A 3 TO 1 RATIO.

SCREENING BENEFITS

* ELIMINATION OF UNNECESSARY REWORK BY REMOVAL OF RECEIVED SUBSTANDARD COMPONENTS AT INITIAL ELECTRICAL TEST

* ELIMINATION OF EXTRA DEPOT REPAIR CYCLES FOR END ITEMS WHICH FAIL DUE TO COMPONENT INSTABILITY OR INFANT MORTALITY

CONCLUSIONS

* ALMOST ALL ELECTRONIC COMPONENTS ARE ACCEPTED INTO THE DOD SYSTEM WITHOUT BEING SUBJECTED TO ANY INDEPENDENT (USER) TESTING.
* IN THE ONE FSC (5961) CURRENTLY SAMPLE TESTED BY DESC ONLY 40% RECEIVE THIS ADDITIONAL SCRUTINY.
* BASED ON THE SAMPLE TEST RESULTS FOR FSC 5961 COMPONENTS:
  - AN ENTIRE LOT IS ACCEPTED IF A SMALL SAMPLE PASSES ELECTRICAL TEST
  - COMPONENT LOTS ARE ACCEPTED EVEN IF THEY CONTAIN LESS THAN A STATISTICALLY-DETERMINED PERCENTAGE OF SUBSTANDARD PARTS

BOTTOM LINE: IT IS IMPOSSIBLE TO GUARANTEE DELIVERY OF 100% GOOD PARTS TO A GOVERNMENT USER ON A ROUTINE BASIS

FUTURE DIRECTIONS

* INCREASED ATTENTION TO COMPONENT PROBLEMS WILL IMPROVE BUT NOT CURE SITUATION

* ECONOMICS FAVOR CONTINUED INDUCTION OF HIGH VOLUME PARTS INTO THE ECS PROGRAM

ENVIRONMENTAL STRESS SCREENING

WR-ALC FUTURE APPLICATIONS OF ESS PRINCIPLES:

* INVESTIGATE USE ON REPAIRED SHOP REPLACEABLE UNITS
* DEFINE FAILURE MECHANISMS FOR CANDIDATE SHOP REPLACEABLE UNITS (SRUs)
* SELECT 5-7 TYPES OF HIGH HARDWARE FAILURE SRUs
* DEVELOP STRESS SCREENS FOR SELECTED TYPES OF SRUs
* EVALUATE IN THE FIELD AGAINST CONTROL GROUP
* EVALUATION TO BE COMPLETED SUMMER '86
* IF SUCCESSFUL, WR-ALC TO IMPLEMENT STRESS SCREENING AS PART OF AVIONICS REPAIR PROCESS

The next speaker, Mr. C. E. (Neil) Mandel, also discussed stress screening but from the perspective of the Institute of Environmental Services (IES). The viewgraphs from his presentation are in this report.

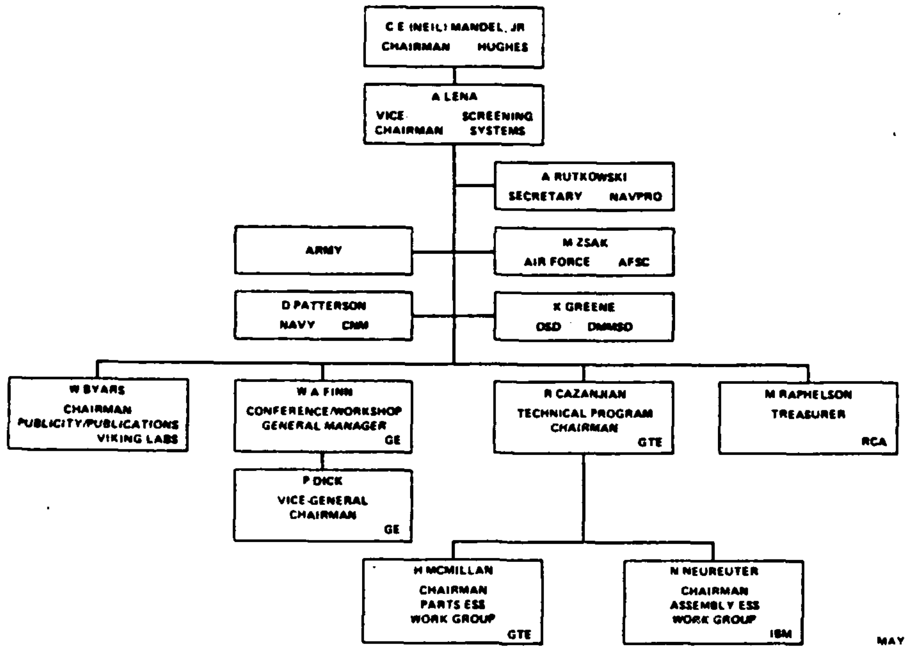
INSTITUTE OF ENVIRONMENTAL SCIENCES ENVIRONMENTAL STRESS SCREENING ACTIVITY

ESSEH CURRENT PROJECTS

- ASSEMBLY ESS GUIDELINE DOCUMENT
- THIRD NATIONAL CONFERENCE AND WORKSHOP (ASSEMBLIES)
- 2 REGIONAL WORKSHOPS ON PARTS SCREENING
- PARTS ESS GUIDELINES DOCUMENT
- FOURTH NATIONAL CONFERENCE AND WORKSHOP (PARTS)

MAY 84/CEM

ESSEH TECHNICAL COMMITTEE



MAY 84/CEM

THIRD NATIONAL CONFERENCE AND WORKSHOP
SEPT 10–13, 1984 PHILADELPHIA, PA

EVENTS

- KEYNOTE ADDRESS – MR. WILLIS J. WILLOUGHBY, JR. DEPUTY CHIEF OF NAVAL MATERIAL FOR R/M AND QA
- EXECUTIVE PANEL – MANAGEMENT AND COST ASPECTS OF ESS
- PLENARY SESSION – TECHNICAL PAPERS
- PANEL SESSION – RANDOM VIBRATION
- PANEL SESSION – MIL-STD-883C/MIL-M-38510F MIL-STD-1772 ISSUES
- WORKSHOP SESSIONS
  - INTRODUCE AND DISCUSS NEW ASSEMBLY GUIDELINE DOCUMENT
  - PART SCREENING DEVELOPMENTS

MAY 84/CEM

ASSEMBLY ESS GUIDELINES DOCUMENT

FEATURES

- COMPLETE UPDATE OF ESS GUIDELINES FOR MODULE, UNIT AND SYSTEM LEVELS OF ASSEMBLY
  - △ DATE BASE – APPROXIMATELY 50 NEW DATA SETS
- REVISION OF COST ANALYSIS SECTION
  - △ SIMPLIFY FOR USER
  - △ ADD FLOW DIAGRAMS RELATIVE TO CALCULATING SCREENING COST, IN-HOUSE SAVINGS AND FIELD SAVINGS
- NEW TOPICS TO BE COVERED
  - △ MANAGEMENT
  - △ RECOMMENDED PRACTICES
  - △ DYNAMICS OF ESS PROGRAM
  - △ PROGRAM NEEDS

MAY 84/CEM

THIRD NATIONAL CONFERENCE AND WORKSHOP PARTS PROGRAM

- HIGH DENSITY MEMORY DEVICE SCREENING TECHNIQUES
- DISCUSSION OF SCREENS VS PART APPLICATION AND DEVICE PACKAGE
- IMPACT OF MIL-STD-883C/MIL-M-38510F/MIL-STD-1772 – PANEL
  - △ OEM
  - △ PART VENDOR
  - △ GOVERNMENT
- APPROACH TO IMPROVED CONTROL OF DEVICE MANUFACTURER ESS
  - △ GOVERNMENT
  - △ OEM
- GUIDELINE DOCUMENT STATUS/ISSUES

MAY 84/CEM

PARTS ESS GUIDELINE DOCUMENT

PURPOSE

- DOCUMENT CURRENT SCREENING PRACTICE AND RESULTS
- DISCUSS SCREENING CHALLENGES ASSOCIATED WITH NEW TECHNOLOGY
- PROMOTE DISCIPLINED APPROACH TO ESS PROGRAM DEVELOPMENT
  - △ CLASSIFY SCREENS BY PARY TYPE/ATTRIBUTE/ FAILURE MECHANISM
- PROMOTE COMMON BASELINE OF UNDERSTANDING OF ESS

STATUS

- DATA BASE TO DATE – 15.5 MILLION PARTS
- FINAL DATA BASE – > 40 MILLION PARTS
- DOCUMENT 60% COMPLETE

MAY 84/CEM

PLAN FOR DEVELOPMENT OF PART ESS GUIDELINE DOCUMENT

- DATA COLLECTION/ANALYSIS: SEPT '81 → JAN '85
- DRAFT GUIDELINES: SUMMER '83 → CONTINUING
- DISCUSSION OF ISSUES – ESSEH CONFERENCE/WORKSHOP
  - △ SEPT '84 – PHILADELPHIA, PA
- REGIONAL PARTS WORKSHOP NO. 1 – PHILADELPHIA, PA – SEPT '84
  - △ CRITIQUE DRAFT GUIDELINE DOCUMENT
- REGIONAL PARTS WORKSHOP NO. 2 – SAN JOSE, CA – SPRING '85
  - △ CRITIQUE 2ND DRAFT GUIDELINE DOCUMENT
- FOURTH NATIONAL IES ESSEH CONFERENCE/WORKSHOP – SAN JOSE, CA – SEPT '85
  - △ INTRODUCE PARTS GUIDELINE DOCUMENT

MAY 84/CEM

PARTS ESS GUIDELINE DOCUMENT

OUTLINE

- INTRODUCTION/SCOPE/PARTICIPANT ACKNOWLEDGEMENT
- FACTORS AFFECTING ESS REQUIREMENTS
- PART SCREENING METHODS FOR MICROCIRCUITS
  - STABILIZATION BAKE
  - TEMPERATURE CYCLING
  - CONSTANT ACCELERATION
  - PIND TESTING
  - HERMETICITY
  - MECHANICAL SHOCK
  - MECHANICAL VIBRATION
  - BURN-IN
- DEVELOPMENT OF ESS PROGRAM EXISTING TECHNOLOGY
  - △ LEVEL OF PARTS TO PROCURE – HOW DETERMINED
  - △ SCREENING PARAMETERS
  - △ OPTIMIZATION/TAILORING
  - △ RE-SCREENING
    - CRITERIA/RISK
    - OEM VS SCREENING HOUSE

MAY 84/CEM

PARTS ESS GUIDELINE DOCUMENT

OUTLINE CON'T

- DEVELOPMENT OF ESS PROGRAM NEW TECHNOLOGY
  - △ EXAMPLE: 256 K RAM
    - ☐ PROCESS EVALUATION
    - ☐ ANALYSIS OF FAILURE MECHANISM
    - ☐ UTILIZATION OF STEP-STRESS TECHNIQUE
- MANAGEMENT CONSIDERATIONS
- PLASTIC PARTS
  - △ FAILURE ANALYSIS/DPA
- SHELF TIME VS RESCREEN
- USE OF ACCELERATED SCREENS

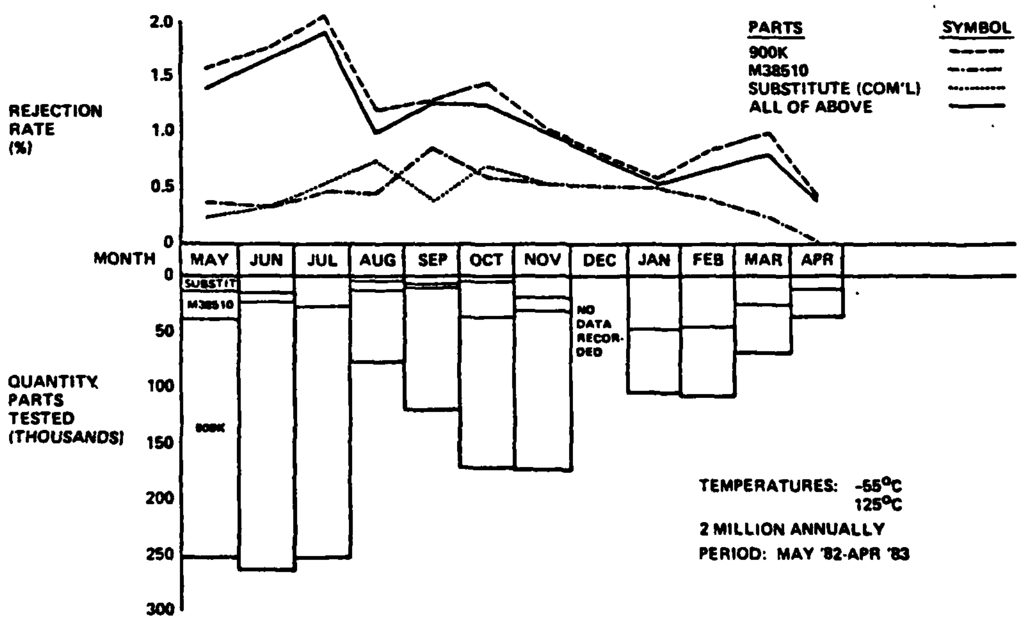
MAY 84/CEM

OUTLINE CON'T

- DIE RELATED FAILURE MECHANISMS VS POSSIBLE SCREENS
- INNOVATIVE SCREENS
- INDUSTRY DATA/CONCLUSIONS
  - △ FIELD FAILURE BREAKOUT BY TECHNOLOGY TYPE

MAY 84/CEM

MONTHLY TREND CHART
100% RECEIVING ELECTRICAL TEST RESULTS FOR DIGITAL INTEGRATED CIRCUITS AT RSGMD



MAY 84/CEM

ESS ISSUES

PARTS

- EMERGING TECHNOLOGY (HYBRIDS/VHSIC)
  - △ PRESENT SCREENING METHODS INADEQUATE
    - "883" CRITERIA INADEQUATE FOR NEW DIE & PACKAGES
  - △ FACILITIES NOT GEARED TO NEW TECHNOLOGY
    - PRE-CAP VISUAL
      - MAGNIFICATIONS INADEQUATE
      - SEM DESTRUCTIVE
    - NEW BURN-IN EQUIPMENT NEEDED
  - △ ELECTRICAL TESTS COMPLEX
    - NEW GENERATION T/E NEEDED

ASSEMBLIES

- SEQUENCE OF SCREENS AT BOX LEVEL
- SYNERGISIC EFFECT OF ESSs
- RANDOM VIBRATION SPECTRUM/PARAMETERS*

RECOMMENDATION

*M, M&T EFFORT OVER 3 YEAR PERIOD

MAY 84/CEM

ESS ISSUES

MANAGEMENT

- USE OF GUIDELINE NOMINAL VALUES AS FIRM REQUIREMENTS

  CONSEQUENCES
  - BAD SCREENS
  - DAMAGING SCREENS
  - EXCESSIVE ESS COST

RECOMMENDATION

REQUIRE PROSPECTIVE CONTRACTORS PROPOSE ESS BASED UPON CHARACTERIZATION OF CANDIDATE HARDWARE

MAY 84/CEM

NEEDED INDUSTRY-WIDE

- DISCIPLINED APPROACH TO ESS DESIGN
- POLICY – SOME FORM OF ESS ON ALL DEMONSTRATABLE OR DELIVERABLE HARDWARE
  – DESIGN OF SCREENS DURING FSD TIME-FRAME
- COST ANALYSIS OF EVERY ESS PROGRAM
  – FOR PROPOSAL WORK
  – FOR MANAGEMENT

MAY 84/CEM

Next, Mr. Gary Ludwig, the technical director of the Avionics Engineering Directorate at ASD made some introductory remarks prior to moderating a panel discussion. Mr. Ludwig's remarks and viewgraphs are included here.

AVIONICS INTEGRITY PROGRAM ADDRESS

MR. GARY LUDWIG - PANEL MODERATOR

(10 MINUTES ALLOCATED)

VUGRAPH 1

THANK YOU, JOHN. WE HAVE HAD THE OPPORTUNITY TO SEE THIS AFTERNOON WHAT INDUSTRY IS ACCOMPLISHING IN THE AREA OF RESEARCH INTO INTEGRITY ISSUES. WE HAVE AN IDEA OF WHAT IS IMPORTANT TO ACHIEVE INTEGRITY IN AVIONICS. THE QUESTION THAT MUST NOW BE ANSWERED IS HOW THE GOVERNMENT IS GOING TO ASK FOR IT.

VUGRAPH 2

WE HAVE BUILT UPON THE SUCCESSFUL AIRCRAFT STRUCTURAL INTEGRITY PROGRAM IN DEVELOPING OUR CONCEPT OF A MASTER PLAN TO BE PREPARED BY THE SUPPLIER, SYSTEM INTEGRATOR OR SUBSYSTEM MANUFACTURER. THE PLAN IS TO DESCRIBE THE APPROACH TAKEN TO SATISFY INTEGRITY REQUIREMENTS. THIS PLAN, DEVELOPED IN A PRELIMINARY FORM, IS TO BE SUBMITTED BY THE MANUFACTURER AS PART OF THEIR RESPONSE TO A REQUEST FOR PROPOSAL. THE INITIAL PLAN WILL INCLUDE THE APPROACH THE MANUFACTURER WILL TAKE IN SOME KEY AREAS SUCH AS STRESS ANALYSIS, FAILURE DIAGNOSIS, THERMAL MANAGEMENT, TESTABILITY, DERATING AND STRESS SCREENING. THE INITIAL MASTER PLAN WILL BE USED AS A FACTOR IN SOURCE SELECTION, AND IT WILL BECOME PART OF THE CONTRACT AFTER THE MANUFACTURER HAS BEEN SELECTED AND AGREEMENT IS REACHED AS TO HOW AND WHEN IT WILL BE UPDATED.

VUGRAPH 3

THE AVIONICS INTEGRITY MASTER PLAN IS TO BE DEVELOPED WITH THE GUIDANCE PROVIDED IN THE AVIONICS INTEGRITY MILITARY PRIME STANDARD WHICH EXISTS IN DRAFT FORM NOW. THE STANDARD WILL BE SUPPORTED BY A HANDBOOK TO PROVIDE RATIONALE AND LESSONS-LEARNED GUIDANCE FOR STANDARD APPLICATION, AND IT FOLLOWS THAT A POLICY DOCUMENT OR REGULATION WILL BE NEEDED FOR GOVERNMENT USE.

THE MILITARY PRIME STANDARD WILL OUTLINE HOW THE MASTER PLAN IS TO ADDRESS INTEGRITY DESIGN REQUIREMENTS AND HOW THESE REQUIREMENTS ARE TO BE CONSIDERED DURING DESIGN, DEVELOPMENT AND MANUFACTURING. THE DESIGN REQUIREMENTS ARE TO BE SPECIFIED IN THE SYSTEM SPECIFICATION OR STATEMENT OF WORK ALONG WITH THE ENVIRONMENT USAGE CONSTRAINTS THAT MUST BE USED IN DESIGNING FOR INTEGRITY. THE MASTER PLAN THEN SERVES AS GUIDANCE FOR BOTH GOVERNMENT AND THE MANUFACTURER FOR ASSESSING PROGRESS AT DESIGN REVIEWS.

VUGRAPH 4

WE WANT TO ACHIEVE A BALANCE IN THE AVIONICS DESIGN OF COST, PERFORMANCE, SCHEDULE AND INTEGRITY. WE MUST EMPHASIZE THIS BALANCE EARLY AND FOLLOW THROUGH THE ACQUISITION CYCLE.

VUGRAPH 5

OUR OBJECTIVE IS TO IMPROVE AVIONICS INTEGRITY BY ESTABLISHING REALISTIC, LIFETIME AND DURABILITY REQUIREMENTS AND ALLOW INDUSTRY THE FLEXIBILITY TO RESPOND TO OUR REQUIREMENTS WITH A RATIONAL PLAN SUPPORTED WITH STUDIES AND ANALYSES TO ACCOMPLISH A DESIGN AND PRODUCT WITH INTEGRITY.

VUGRAPH 5 (BOTTOM PICTURE)

OUR IMPLEMENTATION STRATEGY IS AS PICTURED AT THE BOTTOM OF THE VUGRAPH. THE INTEGRITY PROGRAM SERVES TO ESTABLISH THE TECHNICAL APPROACH AND PLAN FOR ACHIEVING INTEGRITY. THIS MUST BE COUPLED WITH A BUSINESS STRATEGY THAT IS ORIENTED TOWARD PROVIDING CONTRACTS WITH INCENTIVES TO THE MANUFACTURER.

AVIONICS ★ INTEGRITY PROGRAM

READINESS

INTEGRITY

AERONAUTICAL SYSTEMS DIVISION

DIRECTORATE OF AVIONICS ENGINEERING

MR. GARY LUDWIG

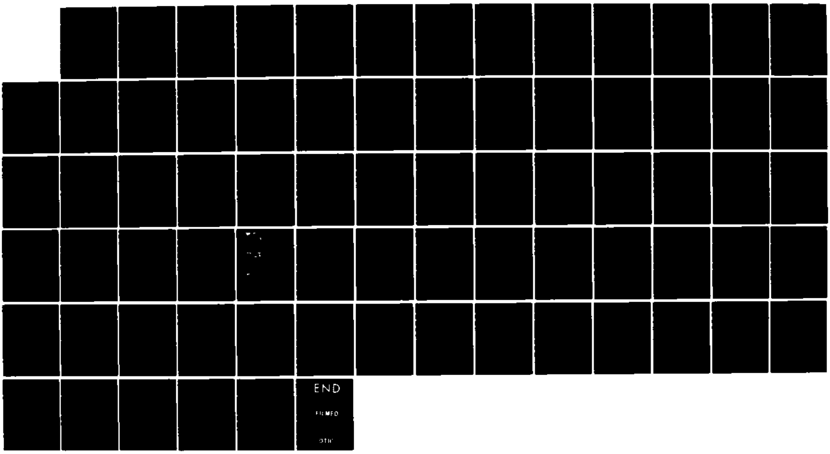
METHOD

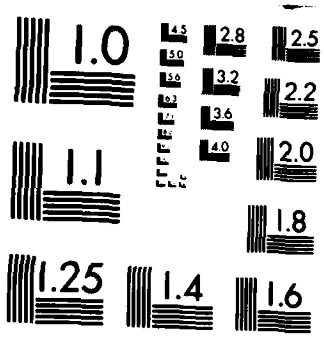
MASTER PLAN

- PREPARED BY MANUFACTURER
- DESCRIPTION OF APPROACH TO SATISFY INTEGRITY REQUIREMENTS
- SUBMITTED WITH PROPOSAL
- INCLUDES:
  - STRESS ANALYSIS
    - FATIGUE
    - CORROSION
  - THERMAL MANAGEMENT
  - DERATING
  - FAILURE DIAGNOSIS
  - TESTABILITY
  - STRESS SCREENING
- CONTRACTUAL

AD-A151 923 AVIONICS INTEGRITY ISSUES PRESENTED DURING NAECON (NATIONAL AEROSPACE AND ELECTRONICS CONVENTION) 1984 (U) AERONAUTICAL SYSTEMS DIV WRIGHT-PATTERSON AFB OH 2/2

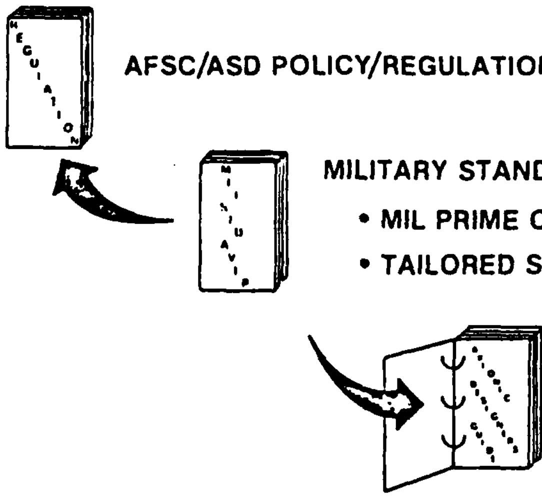
UNCLASSIFIED H C FORTNA DEC 84 ASD-TR-84-5030 F/G 9/5 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

DEFINING DOCUMENTS



AFSC/ASD POLICY/REGULATION

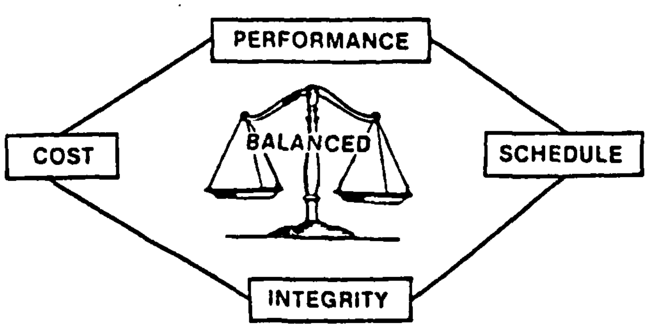
MILITARY STANDARD

- MIL PRIME CONCEPT
- TAILORED SOW LANGUAGE

DESIGNER'S HANDBOOK

METHOD

THE APPROACH TAKEN IN THE MASTER PLAN MUST REPRESENT A REALISTIC BALANCE OF CONSTRAINTS:



CONCLUSION

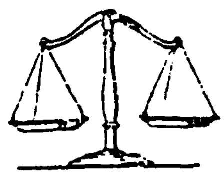
- IMPROVE AVIONICS INTEGRITY -

- APPROACH: DETERMINISTIC PHILOSOPHY
  - DURABILITY
- CONTROL: SERIES OF ACTIVITIES
  - STRESS ANALYSIS
  - DESIGN TO STRESS
- METHOD: MASTER PLAN
  - DESIGN CRITERIA
  - TOOLS

  DESIGN REVIEWS

IMPLEMENTATION STRATEGY

AVIP
DESIGN CRITERIA
TECHNICAL TOOLS



BUSINESS
CONTRACTS, INCENTIVES
& WARRANTIES

After his remarks, Mr. Ludwig introduced the panel members listed below. He gave Mr. Fenter, Dr. Mayer, and Mr. Tewksbury an opportunity to make comments about what their particular AFWAL laboratory is doing in relation to the Avionics Integrity Program. Mr. Ludwig then opened the floor to questions from the audience. He and the panelists were available to answer these questions.

Dr. Joseph L. Capitano, Gould Defense Systems,Inc
Mr. John Devaney, Hi Rel Laboratories
Mr. Donald E. Dewey, Boeing Military Airplane Co.
Mr. John R. Fenter, AFWAL/MLTE
Mr. John Gregory, Westinghouse Defense and Electronics Center
Dr. John Halpin, ASD/EN(PA)
Mr. Ed Koenig, WRALC.MAIE
Dr. Hylan B. Lyon, Jr., Texas Instruments Corp.
Mr. C.E (Neil) Mandel, Jr., Hughes Aircraft Company
Dr. Arnold Mayer, AFWAL/FIE
Dr. Ajay Sharma, IBM
Mr. Alan Tewksbury, AFWAL/AADE-2
Mr. Lou Urban, ASD/AX
Col Dalton Wirtenan, Defense Electronics Supply Center DESC-E

To reflect the essence of this discussion period, key questions and replies are paraphrased below.

Please do not interpret these notes as quotes.

The first question, by Mr. Phil Klass of Aviation Week, was: Are you thinking of applying your program to a product already being manufactured, to a product just starting to be manufactured or are you looking to apply your program to an advanced development program? Or do you hope to apply it to everything from advanced development to production?

Gary Ludwig's response: We do not expect to apply AVIP to programs which are well underway. We are not really prepared to contractually do that. We have been talking very seriously to the ATF Program Office and are looking ahead to when that effort goes into full-scale development. We have also looked at some subsystems and LRU's which are coming up for procurement over the next couple of years where we can try these techniques and the contractual vehicles which might capture them.

Mr. Ed Trumpeter of Trumpeter Electronics, Inc made the following

Mr. Ed Trumpeter of Trumpeter Electronics, Inc made the following comments. ASD and DESC are not living in the real world. It (the acquisition process) just doesn't happen the way you would like it to happen. There are people under you doing things completely in violation of what you are trying to do. In ASD they are violating those specs all over the place. All DESC does is warehouse and distribute parts. Parts, in particular some of my company's parts, are being counterfeited.

Gary Ludwig's response: I don't disagree with your comments, but our program assumes that integrity exists in the contractual relationship, and that there's enough enforcement built-in to try to maintain that integrity and keep the honest, honest. Clearly, if there are proveable cases of fraud, counterfeiting, or whatever they ought to be addressed in our legal system.

A gentleman from McDonnell Aircraft Company made the following comments. You briefly mentioned that industry, while reviewing the first draft of the MIL-STD objected to the amount of paperwork involved. From what I have heard you have not satisfied this objection. It appears that if a contractor says they will meet the requirements of reliability, durability, maintainability and all the other measurable parameters they still have to meet the requirements of the AVIP. This is what industry is objecting to. It is not just the quality of the product they will be measured on but also the quality of the plan which they submit with the RFP.

Mr. Ludwig's response: We don't want more plans. We are trying to respond to ALL the comments we received in that first draft. I don't think you could have honestly reached your conclusion from the few comments you have heard today about the next draft of our MIL-PRIME-STD. I would like you to read this next draft before you make your judgments. We are talking about one plan which will incorporate many others and replace others.

Mr. Dewey's response: When we read the first draft of the AVIP MIL-STD, it looked to us as though we would have to have about 20 people sitting off to the side in order to respond to the requirements of the AVIP. Many in industry had similar comments. These comments were taken to heart. The way it is being handled now is in a tailoring process. This is what was recommended and this is what is going to be done so that the existing processes (paperwork) stay untouched, but they are integrated and they are put into a total package form by an umbrella type of a master plan. There are many of us now in industry who are saying this is an excellent thing to do.

If it (AVIP) is implemented properly (that is tailored properly) it does not have to cost an arm and a leg yet it will identify the problems so that we get the best product out. However, IF, in the contractual arrangement things do get out of hand and there are too many additional requirements on top of the master plan then I will swing back very strongly into your camp.

Avionics Integrity Program Tutorial Notes

The Avionics Integrity Program Tutorial was held on Monday afternoon, May 21, 1984. The participating lecturers for the tutorial are listed on page 96. This tutorial covers the many facets of integrity (thermal management, corrosion control, failure diagnosis, environmental stress screening, combined environmental reliability test, and logistics support analysis) and how they are incorporated in the Avionics Integrity Program.

AVIONICS INTEGRITY PROGRAM

TUTORIAL NOTES

Avionics Integrity Program Office
Directorate of Avionics Engineering
Wright-Patterson Air Force Base, Ohio 45433

Agenda

AVIONICS INTEGRITY PROGRAM TUTORIAL

NAECON '84

MONDAY, 21 MAY 84

Introduction	Mr. John Price (ASD/ENAS)
AVIP Program	Major Lee F. Cheshire Mr. Thomas J. Dickman (ASD/ENAS)
Videotape	Mr. Dave S. Steinberg (Litton)
Videotape	Mr. Willis J. Willoughby, Jr. (NAVMAT 06)
Thermal Management	Mr. Robert L. Berger (ASD/YYEF)
Corrosion Control	Mr. John Kaufhold (ASD/ENAS)
Failure Diagnosis	Dr. Bill Dobbs (AFWAL/MLSA)
Environmental Stress Screening of Electronic Hardware	Mr. Phillip H. Hermes (ASD/YYEI)
Videotape	Mr. Joseph L. Capitano (Gould, Inc.)
Combined Environment Reliability Test (CERT)	Dr. Alan Burkhard (AFWAL/FIEE)
Logistics Support Analysis (LSA)	Mr. Kenneth L. Morris (AFALC/PTA)

Dr. Alan Burkhard is the Technical Manager of the Combined Environments Test Group of the Air Force Wright Aeronautical Laboratories' Flight Dynamics Laboratory. In this capacity he is responsible for the technical direction and content of MIL-STD-810, the tri-service coordinated environmental testing methods document. He was the Technical Program Director of the extensive R&D effort which developed Combined Environments Reliability Test (CERT) into a useful acquisition test technology. Dr. Burkhard has authored over 15 technical papers and open literature reports concerning environmental reliability design and test criteria.

Robert L. Berger is currently Chief of the Flight Systems Division, Deputy for Strategic Systems which is responsible for the Air Launched Cruise Missile (ALCM), the Advanced Cruise Missile (ACM), the F-111 Avionics Modernization Program (AMP), various B-52 modernization programs and the Advanced Air to Surface Missile (AASM). Mr. Berger initiated the Thermal Management Program within the Aeronautical Systems Division and has written two published papers on the topic: "A Systems Approach - Minimizing Avionics Life Cycle Cost," presented at the 13th Intersociety Conference on Environmental Systems in July 1983, and "Electronic Equipment Thermal Management," presented at the 1984 Reliability and Maintainability Symposium in January 1984.

Mr. Berger graduated from Ohio University (BSME) in 1967, the University of Dayton (MSEM) in 1972, and the Air War College Seminar Program in 1977. He is a member of AIAA and a registered Professional Engineer in the State of Ohio.

Major Lee F. Cheshire (USAF) is currently assigned to AFSC/ASD, more specifically to the Directorate of Avionics Engineering, where he has managed the Avionics Integrity Program since November of 1982. Previously he was assigned to the Controls and Displays Branch of ENAS for 8 months. He has a BSEE from the University of Virginia (1970) and an MS in Aeronautical Systems Engineering from the University of West Florida (1972). Major Cheshire is a certified private pilot with an instrument certificate. Since being stationed at Wright-Patterson Air Force Base, he has worked on such projects as the HH-60D Nighthawk Source Selection, Advanced Tactical Fighter, standard fiber optics data bus, and avionics architecture handbook. He is now a lead engineer and manager for ENAS, working to develop and promote the Avionics Integrity Program.

Major Cheshire was born at Bolling Air Force Base, Washington DC, and is married to the former Anne D. Myers of Alexandria, VA. They have two sons.

Joseph L. Capitano, P.E., Director of Quality Assurance, has been with Gould since 1972. For five years he managed and was responsible for failure diagnostic analysis of all components as well as vendor approval and selection. He also functioned as a Technical Subcontracts Administrator under the direction of the Director of Purchasing. He has been in his present position for over four years. Prior to joining NavCom, he held the positions of Quality Manager for several small aerospace companies. He also has been a Quality Engineer, Chief Failure Analysis Engineer, Test Manager, and Hybrid Quality Engineer. He has over 20 years in aerospace Quality Engineering and related functions. Prior to entering the quality field, he was a Design Engineer in the fields of power supplies, radiation detection equipment, and computer logic design. Mr. Capitano is currently teaching credited Quality Assurance advanced courses at Rio Hondo College, and has done so for the past four years. He has recently completed work on a PhD.

Mr. Thomas J. Dickman is currently assigned to the Directorate of Avionics Engineering where he has been defining, developing, and promoting the Avionics Integrity Program since January 1983. He currently serves as a lead engineer in the Avionics Systems Division where he is technical head of the Avionics Integrity Program. Since coming to Wright-Patterson AFB in 1968, he served as project engineer responsible for the development of air data computers. He has written and presented several papers advocating the development of the Standard Central Air Data Computer. He has authored several articles and papers advocating the Avionics Integrity Program. In 1980, Mr. Dickman was assigned to the Deputy for Tactical Systems as lead avionics engineer for the A-10 Weapon System. Mr. Dickman received a BSEE degree from the University of Cincinnati in 1968. In 1974, he received a Master of Science degree in Engineering Management from the University of Dayton. Mr. Dickman is a registered Professional Engineer in the State of Ohio.

Dr. Bill Dobbs is employed at the Air Force Wright Aeronautical Laboratories/ Materials Laboratory at Wright-Patterson AFB, OH. He has lectured extensively on electronic materials and manufacturing processes associated with electronic device failure. Dr. Dobbs established and organized the Systems Support Division's Electronic Failure Analysis Group at the Materials Laboratory in 1977. He received his Ph.D. in Physics from the University of Missouri at Columbia in 1971 and has research and teaching experience from three post-doctoral fellowships. He has made numerous presentations and has published extensively in scientific journals.

Phillip H. Hermes is currently the Deputy for Strategic Systems (YY) Lead Engineer for Product Assurance. He provides program support in reliability, maintainability, parts control, producibility, and value engineering. In the past, Mr. Hermes has worked in the areas of aircraft vibration, acoustics and shock. The programs he has supported are the F-15, F-16 and B-52 Constant Speed Drive. From 1980-81, he was a member of the National Committee on Environmental Stress Screening, sponsored by the Institute of Environmental Sciences.

Mr. Hermes graduated from Bellarmine College (BA Math) in 1957, the University of Detroit (BSME) in 1960, and the Air Force Institute of Technology (MS System Engineering) in 1974.

After joining the Aeronautical Systems Division in 1970, John Kaufhold specialized in system safety, systems and materials engineering, and corrosion control on mobile shelterized reconnaissance/strike system ground stations for over 12 years. As a member of the Avionics Integrity Program Office, he is responsible for the development and integration of system safety and corrosion control requirements for the Avionics Integrity MIL-PRIME Standard.

Mr. Kaufhold received a Bachelor of Science degree in Chemistry in 1969 from the University of Cincinnati. He is a member of the System Safety Society and the National Association of Corrosion Engineers.

Kenneth L. Morris is a Logistics Management Specialist in the Directorate of Logistics Support Analysis, Air Force Acquisition Logistics Center at Wright-Patterson Air Force Base, Ohio. In 1979 he directed the study to determine the course of action the Air Force would take in implementing LSA. His final report and recommendations was the foundation for the Air Force LSA development program. He served as the AFLC representative to the AFLC/AFSC steering group established to direct the LSA implementation program and was also a member of the OSD-sponsored Joint Service/Industry Work Group that rewrote MIL-STD-1388. With the formal publication of the MIL-STD, Mr. Morris' principal function has been to act as a consultant to Program Offices implementing LSA on acquisition programs.

Dave S. Steinberg is the Manager of the Mechanical Engineering Design Analysis Section at Litton Guidance & Control Systems, in Woodland Hills, California. He is a Registered Professional Engineer in New York, New Jersey and Michigan, and the author of more than 20 published articles on Electronic Packaging. In addition, Mr. Steinberg is the author of two textbooks, "Vibration Analysis for Electronic Equipment" and "Cooling Techniques for Electronic Equipment" which are published by John Wiley & Sons, in New York.

Mr. Steinberg received his B.S. Degree in Mechanical Engineering from the Illinois Institute of Technology in 1948. He is a visiting Professor at the University of Wisconsin-Extension, where he has been presenting a series of short courses on vibration and cooling of electronic equipment for the past 6 years.

At the request of Admiral Isaac Kidd, Chief of Naval Material, Mr. Willis J. Willoughby came to the Headquarters Naval Material Command as the Director of the Reliability and Maintainability Directorate in 1973. Prior to "joining" the Navy, Mr. Willoughby was the Director of Apollo Reliability, Quality and Safety for the National Aeronautics and Space Administration's Office of Manned Space Flight, Apollo Program Office.

Mr. Willoughby earned a BSME in 1952 from the University of South Carolina. His awards include the

* President's Meritorious Executive Award
* NASA Exceptional Service Medal
* Navy Distinguished Civilian Service Award
* Apollo Group Achievement Award
* Aerospace Industries Association (AIA) Distinguished Colleague Award
* Aeronautical Institute of Aeronautics and Astronautics (AIAA) Systems Effectiveness and Safety Award
* Institute of Environmental Science (IES) Reliability Test and Evaluation Award
* Society of Logistics Engineers (SOLE) Logistics Award

Mr. Willoughby was born in Columbia, and is married to the former Mary J. Lloyd. They have two sons and one daughter.

The videotape you are about to see is an introduction Lt Gen T H McMullen, ASD Commander prepared for the videotape "A New Dimension in Weapon Systems Design", which stars Gen Robert T. Marsh, Commander, Air force Systems Command, Gen Billy M. Minter, Commander, United States Air Force Europe, and Gen James Mullins, Commander, Air Force Logistics Command. Several of Gen McMullen's comments refer to the film and his overall message is clear. The Avionic Integrity Program and NAECON's theme this year address these issues. Here is the script for the videotape.

The message you are about to see is an important one. Its about logistics and supportability and availability of weapons systems, but its not directed at the people we normally think of in those areas. Its aimed right at us - here in ASD. It talks about our business, technology, and system acquisition, but not from the perspective we historically emphasize - how fast, how high, how far. It talks of the importance of having machines that are available to show their stuff rather than sitting somewhere on jacks leaking hydraulic oil. Its not a new idea. What is new is a matter of emphasis. The interest in addressing these issues early, of building in this capability rather than trying to force it in afterward. As you'll see there are several spokesmen who develop this theme. The principle ones though are Gen Marsh, our boss, Gen Minter, who is squarely facing our potential enemy as the commander in Europe, and Gen Mullins, whose command suports the systems we field. We at ASD are major players in this important subject.

As Systems Command's principal acquisition organization, we need to focus our attention toward more available weapon systems. The message is simple: it is our job to see the systems we acquire - the fighters, the bombers, the missiles, in fact all the aeronautical equipment we provide - are designed, developed, manufactured, and fielded with the support needed to provide the combat troops the opportunity to be a credible deterrent force; or failing that, a force that will win no matter what the environment.

Now, here at ASD, we're taking beginning steps to increase attention to the importance supportability and sustainability play in specifying both hardware and software. It all has to begin in the important work done in our labs where so much of our technology begins. As you'll see, Keith Collier has some things to say from that aspect.

But the consciousness must grow as the system takes shape. We all know that fielding supported systems requires discipline in both our design and manufacturing process. Our systems have to be developed so they're consistent with the support concepts and requirements of both the operating and supporting community. To help provide that orientation and to help with the policy necessary to increase our emphasis on a supported system, we have two fairly new organizations at ASD. First, in the Deputy for Engineering, the ASD Product Assurance Office now headed by Dr. John Halpin. Its chartered to help our focus on reliability, maintainability and quality in design and manufacturing. I've also established the Deputy for Acquisition Logistics under Colonel Dave Casey, to exercise management oversight of ASD acquisition logistics functions and activities.

While these two organizations are fundamental to our institutional approach to these areas, as always, the place where it happens is in our program offices, where the program director has the responsibility for how we do or don't do our work in this particular area as elsewhere. The challenge we face requires not more work but smarter work from all of us. It requires that we increase our knowledge and involvement in ensuring that availability in all its subsets - like readiness, supportability and sustainability - are integrated into the right aspect of our acquisition program.

Incidently we have initiated such efforts right on the ground floor in the advanced tactical fighter. There, we have a chance to back off and run at it from the start. But we can't limit this new enthusiasm to just new starts or programs whose development cycle is out in the future. We have shown we can do it in lots of ways. Probably, our best example is the Alternate Fighter Engine Program. Their innovative management and dedication and leadership all teamed up to give us fighter engines that will spend lots more of their lifetime propelling airplanes rather than in the engine shop.

But we just have to do more. We have to do it with all our programs - now. We must turn all our programs toward, and where it's clearly not too late, into being fully supported when we turn them over to the user. This film clearly highlights that support isn't something we add on to our systems. It's an integral part of the design and manufacture of the hardware. It requires the appropriate resources be committed to providing the right level of support and we must have the final say on how that goes. I suggest you pay careful attention to the story these three leaders unfold.

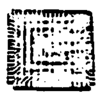
AVIONICS INTEGRITY PROGRAM (AVIP)

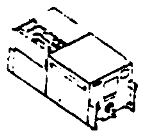
OVERVIEW

- BACKGROUND
- DURABILITY
- ACTIVITIES
- PROGRAM
- CONCLUSION

This tutorial will first provide a background of ASD's Avionics Integrity Program (AVIP) and its development from the Aircraft and Engine Structural Integrity Programs. Next, the technical perspective and philosophy of durability will be discussed. Then the acquisition activities necessary to achieve integrity of hardware will be discussed in detail. Guest speakers will be phased into the tutorial as we develop the AVIP process. Finally, the status of the AVIP program will be provided.

AVIONICS REALITIES



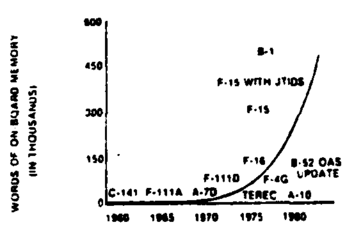


- PERFORMANCE/TECHNOLOGY DRIVEN
- TECHNOLOGY RAPIDLY ADVANCING
- EXPANDING ROLE
  - MISSION ESSENTIAL
  - SAFETY-OF-FLIGHT
- RELIABILITY INCREASING (PART LEVEL)
- COMPLEXITY INCREASING
- QUANTITY INCREASING
- CONSTRAINED MANPOWER AND LOGISTICS SUPPORT ENVIRONMENT

Avionics are being driven by performance and technology and are expanding into mission essential roles such as electronic warfare and weapon management systems and safety-of-flight roles such as flight and engine controls. Reliability may be increasing at the part level but increasing complexity and quantities decrease system reliability and burden the logistics support environment. The exponential increase in words of onboard memory exemplifies the situation.

AVIONICS REALITIES

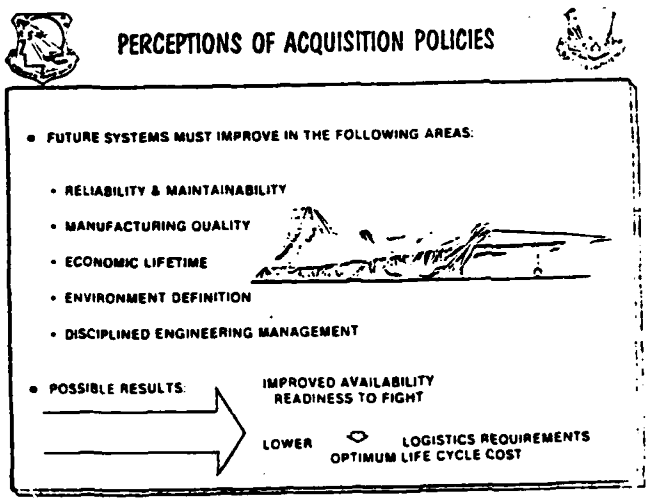
THE CLIMBING AVIONICS REQUIREMENT *



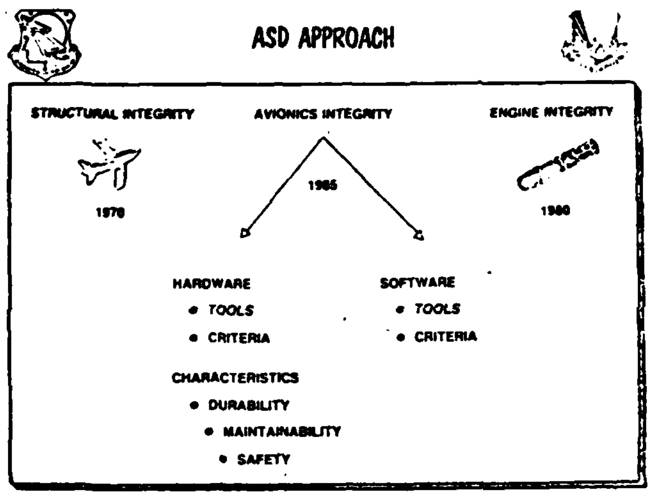
* AIR FORCE MAGAZINE/JULY 1983

"WHAT THE COMPUTER HATH WROUGHT"

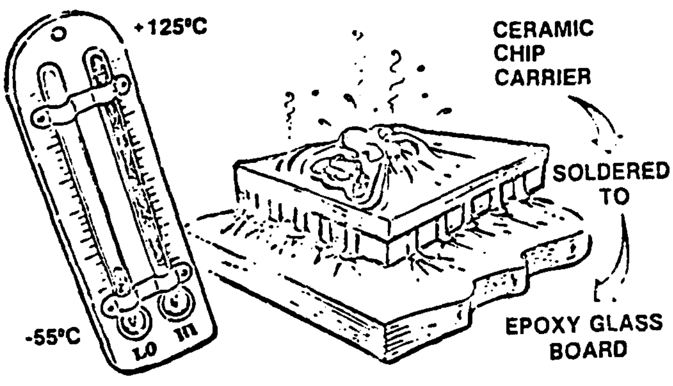
- WALTER LANG



In order to meet these realities we need to improve the reliability and maintainability, manufacturing quality, economic lifetime, and environment definition of our hardware. These, along with a disciplined engineering management approach should lead us to improved readiness with reduced life cycle cost.

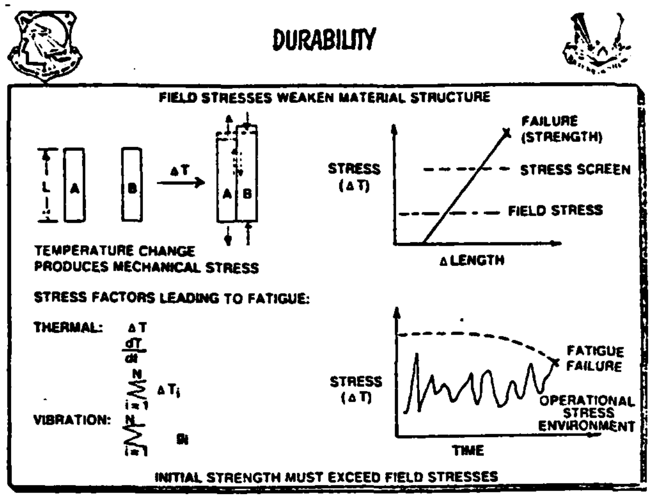


In the past ASD established the Aircraft Structure Integrity Program (ASIP) and the Engine Structure Integrity Program (ENSIP) to improve the quality of these key airplane elements. The ASIP began in the late 1950's because of a wing cracking problem on the B-47. There were two basic problems: there was a need for improved design criteria and selection of materials for wings and there was a need for improved manufacturing techniques and better control of the manufacturing process. The late 60's and early 70's saw an improved ASIP with the advent of fracture mechanics and the analysis of crack growth on the wings to the point where a wing's lifetime could be more accurately determined based on the usage of the wing. Today, virtually all USAF aircraft are using ASIP and the commercial industry is applying the same principles to their aircraft. The ENSIP began in 1970's and applied similar concepts to improving the integrity of aircraft engines. The realities of avionics has led us to the Avionics Integrity Program where we are presently addressing hardware quality (software quality will be addressed in the future) by establishing the tools and criteria necessary to obtain these characteristics of integrity: durability, maintainability, and fault tolerance/safety.

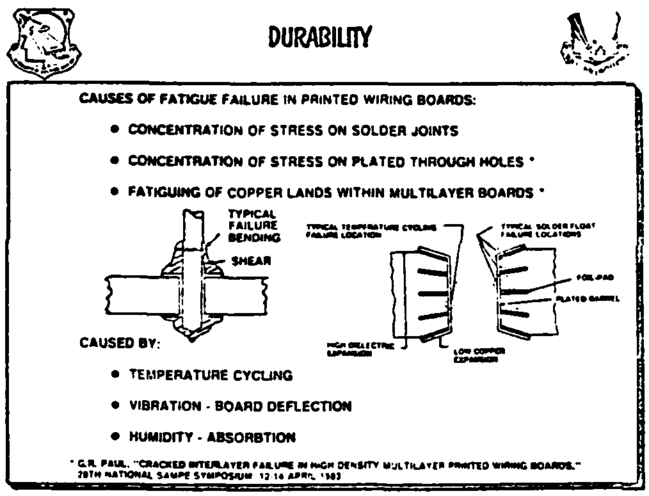


THERMAL COEFFICIENTS OF EXPANSION

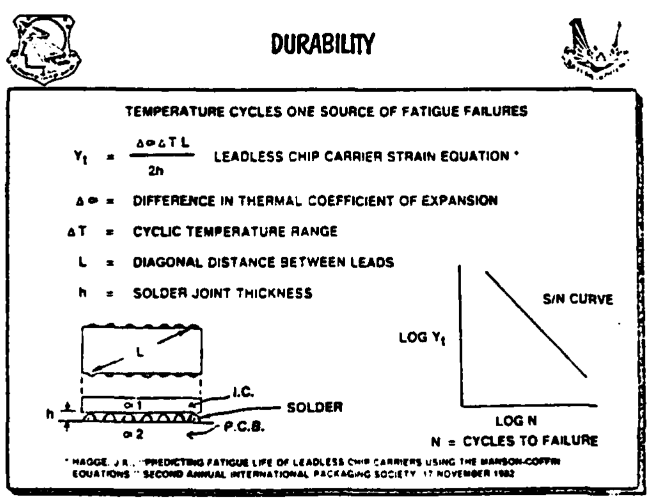
One of the major causes of failures in avionics is the differences in thermal coefficients of expansion between various components of electronic equipment. This is a graphic example of the results of thermal gradients on a chip carrier and the board to which it is soldered. Avionics designs must be able to tolerate these differences - they must be rugged (durable).



In order to explain our concept of durability, an application of basic principles of thermodynamics to electronic structures is helpful. Differences in thermal coefficients of expansion cause mechanical stresses to be set up at the interface of two materials bonded together. These stresses are plotted in the upper right as a function of change in length of the bonded pair of bars. If we heat the bars to the point where their expansion causes the interface of the two bars to rupture, we have reached the yield strength of the joint. Operational or field stresses are well below this maximum strength point. Stress screening is intended to insure that the part will not fail in the presence of field stresses. We introduce stresses greater than the parts will typically experience to precipitate out weak joints. In the lower right we recall that repeated stress cycling reduces the strength of the joint and that time to failure is the joint's fatigue life. In the lower left we are reminded that there are fatigue factors in addition to thermal cycling that include the rate of change of temperature with time and vibration cycling.

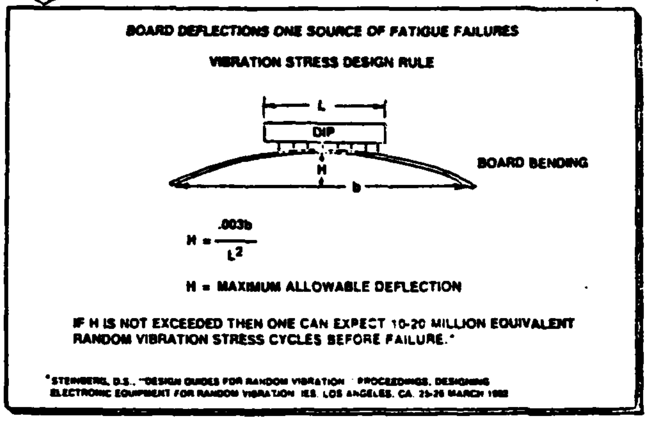


Fatigue failures can occur in printed wiring boards as well as in the electronic components themselves. The method of attaching components to printed wiring boards and the fabrication of the boards themselves can create potential fatigue points. Solder joints where leads are mounted through the board can be susceptible to fatigue failure. The complex multilayer boards have many fatigue failure modes caused by temperature cycling, vibration and board deflection, and absorption of fluid which causes out of plane expansion. Industry is aware of these factors as indicated by the number of articles on the subject in the technical literature.



This viewgraph characterizes the effect of temperature cycles on leadless chip carriers. The designer can control the lifetime of the interface. This will be explained in more detail in the forthcoming videotape.

DURABILITY



The effect of vibration on printed circuit boards has been studied and there are ways to control the life of a board in this environment as Mr. David Steinburg will show us in the following videotape.

PACKAGING ELECTRONIC EQUIPMENT

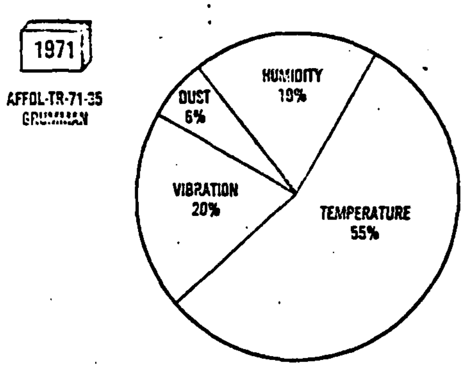
FOR

SEVERE ENVIRONMENTS

by

Dave S. Steinberg

ENVIRONMENTAL INDUCED FAILURES

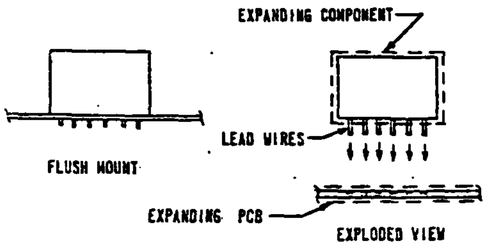


COST TO AIR FORCE - $163 MILLION / YEAR

* Study by Grumman
* Found a number of failures occur in avionics equipment
* Greatest number of failures due to temperature (related to materials - coefficients of expansion, modules of elasticity - not junction temperatures) and temperature cycling
* Vibration and humidity also accounted for a large percentage of the failures

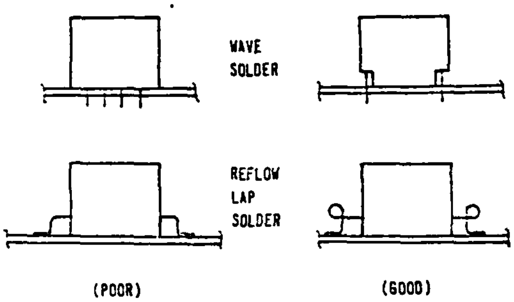
AVOID FLUSH MOUNTED ELECTRONIC COMPONENTS

THERMAL EXPANSION GENERATES STRESSES IN SOLDER JOINTS



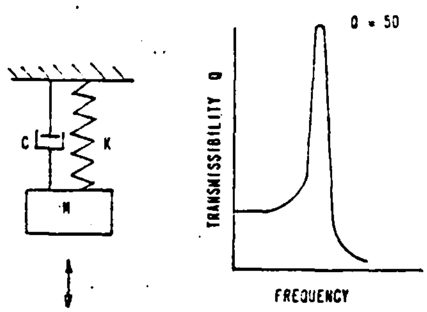
* Temperature cycling: mismatch of materials (high coefficients of expansion, high modules of elasticity, low strain relief or no strain relief) results in high stresses in solder joint
* Failures precipitated by temperature cycling, coefficients of expansion and high moduli of elasticity
* Failures show up in vibration environment
* Typical temperature cycling: 3 cycles/day
* Typical vibration: 300 cycles/second

MOUNTING TRANSFORMERS



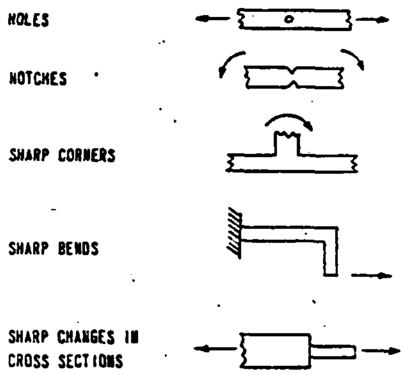
* To reduce failures generated in temperature cycling: provide strain relief for component lead wires
* Example: encapsulated or potted modules flush mounted to curcuit card - when circuit board and component module expand there is no place for force to go - consequently, solder joint cracks

MOST FAILURES ARE DUE TO A SEVERE RESONANT CONDITION



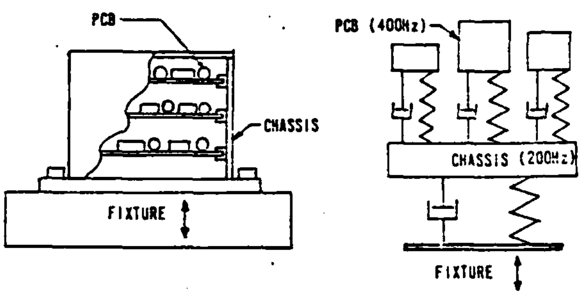
* Vibration environment: single biggest cause of failure is development of a severe resonance
* Although systems are very complex, they can be represented by a single degree of freedom system fairly accurately
* When systems exhibit a resonance, can have transmissibility of 50-100
* Therefore, stresses will be 50-100 times greater than those at normal g-loading

STRESS CONCENTRATIONS



* Vibration environment: second biggest cause of failureis stress concentrations
* Here the stress riser may be 2 to 3 or maybe even 4 - no where near the 50 or 100 that you can get in a resonant condition
* Stress concentrations must be examined very closely
* Insure there are no holes in improperly located areas, no sharp corners or no changes in cross sections
* Must be watched carefully to reduce stresses and improve fatigue life in various dynamic environments

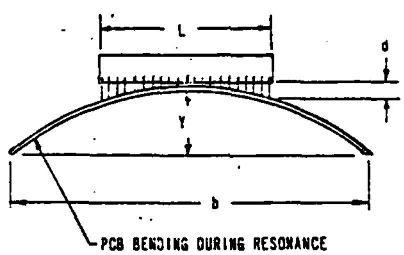
REDUCE FAILURES WITH THE USE OF THE OCTAVE RULE



DOUBLE THE NATURAL FREQUENCY FOR EVERY ADDED DEGREE OF FREEDOM

* Systemas multiple degree of freedom system
* Chassis: first degree of freedom becauseit receives dynamic energy first
* Circuit cards: usually attached to chassis,receives energy second, represent second degree of freedom
* Should be no coincident resonances between chassis and circuit card because transmissibilities multiply, i.e., chassis Q=10, circuit card Q=10, circuit card receives Q=10 X 10 =100
* We must be able to design circuit card to minimize dynamic stresses; that means, controlling resonances
* We have to live withresonances because it isn't possible to design a resonant-free system for up to 5000 cycles (exciting frequencies up to 5000 cycles)
* Have to "tune" the system; example: circuit card has resonance of 400 Hz; to minimize the possibility of coupling, the resonances need to be separated by an octave; chassis resonance will be 200 Hz (vibration environment)
* Shock environment opposite end of spectrum; example: if curcuit card has resonance of 400 Hz, by the reverse octave rule the chassis resonance will be 800 Hz

MOUNTING LARGE COMPONENTS

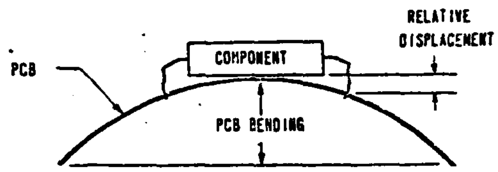


* 40 pin DIP, 2 inches long, mounted at the center of the circuit card
* As the circuit card stresses during resonant condition there is a large amount of strain in the lead wires
* In a 10-g random vibration environment,a 40 pin DIP on a 6 inch X 8 inch circuit card will typically last 50-60 seconds

PCB DESIGN

FAILURES OCCUR IN COMPONENT LEAD WIRES AND SOLDER JOINTS

DUE TO LARGE DYNAMIC DISPLACEMENTS, WITH POOR STRAIN RELIEF



* Discrete components (resistors, diodes, etc.)
* Will exhibit similar characteristics to the 40 pin DIP in the previous slide
* As the circuit card stresses, component lead wires will flex and bend
* When there's enough stress and a sufficient number of fatigue cycles, a failure will occur

DYNAMIC EQUATIONS

$$Y_{rms} = \frac{9.8\, G_{rms}}{(N_0^+)^2} \quad \text{--- (1)}$$

$$Y_{all} = \frac{0.003\, b}{L^2} \quad \text{--- (2)}$$

$$G_{rms} = \sqrt{\frac{\pi}{2} D\, f_n\, Q} \quad \text{--- (3)}$$

$$Q = \sqrt{f_n} \quad \text{--- (4)}$$

* To quantify failures and determine how systems will act
* To determine fatigue life in various environments
* Simulate complex systems as a single degree of freedom system (loses accuracy, but willing to sacrifice accuracy for expediency)
* Analysisis accurate enough to "keep us out of trouble"
* When the system has fair credibility for mechanical design, "fine tune" it with the use of a finite element computer program
* Theequationsareforacircuit board
* The first equation gives the root-mean square (RMS) displacement in the random vibration environment: N_o^+ is the number of positive zero crossings
* The second equation is empirical equation based on years of testing of actual hardware and obtaining failures witn different types of environments; need to keep the maximum dynamic single amplitude displacement of the curcuit board to $0.003b/L^2$ (b is the length of the circuit card parallel to the component, L is the length of the component)

* the third equation is the random response of a single degree of freedom system that we are using to approximate a circuit board: D is the power spectral density, f_n is the natural frequency as though it is subjected to a sinusiodal or harmonic motion, Q is the transmissibility experienced in this environment
* the fourth equation says that for a plug-in type of circuit card, a good approximation of tne transmissibility at the resonant condition is the square root of the natural frequency (good for frequencies of 150-300 Hz; below 100 Hz, Q is about 0.7 of the natural frequency and above 400 Hz, Q is 1.2 or 1.3 times the square root of the natural frequency)
* the *combination of* these equations is used to determine the natural frequency our system needs to obtain a fatigue life of 10^7 cycles

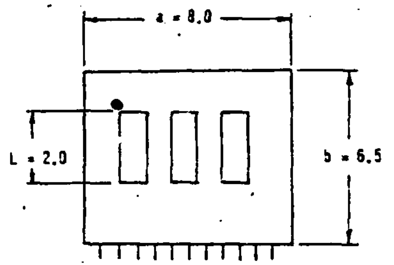
DESIRED PCB RESONANT FREQUENCY (f_n)

FOR 3 SIGMA ACCELERATIONS

$$f_n = \left[\frac{9.8\, L^2 \sqrt{\frac{\pi}{2} D}}{.001\, b}\right]^{0.8}$$

* Equation obtained when the previous four equations are combined
* Computes desired natural frequency for 10 million stress reversals in the component lead wires
* Used for random vibration applications

SAMPLE PROBLEM



PLUG IN PRINTED CIRCUIT BOARD (PCB)

* 8.0 X 6.5 inch circuit card
* Components parallel to 6.5 inch side of circuit card
* 40 pin Dual In-line Package (2 inch Long)
* Component mounted at center of circuit card
* Assume card is simply supported on four edges; connector will act as a hinge; side supports are typically hinges unless they are wedge clamped (wedge clamps give a very high mechanical advantage such that the boundary conditions are more hinged; the ability to clamp is a function of frequency - the higher the resonent frequency, the less effective the wedge clamp becomes; with frequency of 150 to 300 hz range, wedge clamp can act as an effective clamp)

$$f_n = \left[\frac{9.8\,(2)^2 \sqrt{\frac{\pi}{2}(.04)}}{.001\,(6.5)}\right]^{0.8}$$

$$f_n = 349 \text{ Hz}$$

* Compute desired natural frequency of arrangement on previous viewgraph
* Use power spectral density of 0.04 g^2/Hz
* D was obtained based on the NAVMAT P-9492 stress screening test (also known as the Willoughby screening test)
* Now divide by .001 because the 3 sigma acceleration causes most of the damage and must be considered; the RMS and 2 sigma (2 X RMS) points do little damage
* A desired natural frequency of approximately 350 Hz is needed to give us at least 10 million stress reversals in the lead wires

DURABILITY

DEFINITION: USEFUL LIFE - ABILITY OF AVIONICS TO FUNCTION AND SUSTAIN STRESSES IN THE ENVIRONMENT WITH ECONOMICAL MAINTENANCE

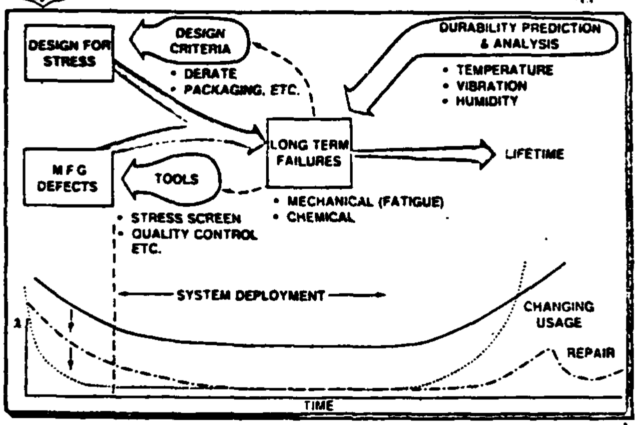
STRESSES	ENVIRONMENT	MAINTENANCE
• ELECTRICAL	• OPERATIONAL	• TESTABILITY
• CHEMICAL	• MAINTENANCE	• ACCESSIBILITY
• MECHANICAL	• STORAGE	• REPAIRABILITY
• THERMAL	• SHIPPING	• LOGISTICS SUPPORTABILITY
	• MANUFACTURING	

DESIGN CRITERIA:
- FATIGUE LIFE
- CORROSION CONTROL
- THERMAL MANAGEMENT
- DERATING

TOOLS:
- STRESS SCREENING
- STATISTICAL QUALITY CONTROL
- STRESS ANALYSIS

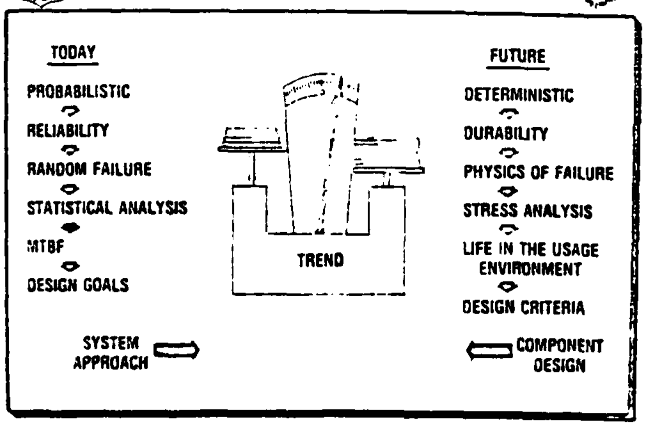
The definition of durability is given here with further explanation of key words in the definition. The design criteria and tools necessary to obtain durability are also listed here.

DURABILITY

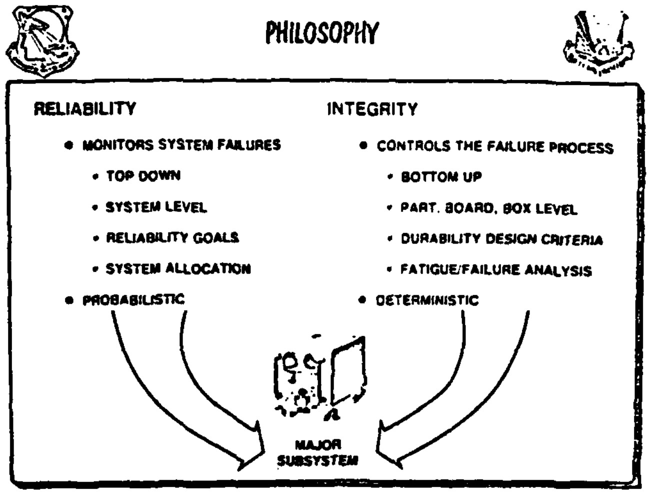


If proper design criteria and production tools are applied, the result is a "design for stress" and reduced manufacturing defects. These reduce the failure rate, (bathtub curve - solid line in graph) to the lowest level (dotted line on graph). The longterm failures can be addressed through a durability prediction and analysis and the longterm lifetime (the rise on the dotted line) is unmasked. The knowledge about the longterm failures also results in a synergistic effect if fedback into the design and manufacturing activities. Thus, improvement of the design and manufacturing techniques is achievable through a more deterministic approach.

PHILOSOPHY



What this leads to is a changing philosophy toward engineering design and quality products. We are moving away from the probabilistic, systems approach of today toward the deterministic, component approach of tomorrow.



Showing this philosophy in a different way we can see that these two approaches can play together to produce a better quality system. The MIL-HDBK-217D approach results in an excellent preliminary subsystem design from the reliability philosophy. The bottom up, durability discipline can then be applied to the detailed subsystem design.

DEFINITION

WHAT IS INTEGRITY?

AVIONICS INTEGRITY IS A DETERMINISTIC APPROACH TO IMPROVE THE OPERATIONAL CHARACTERISTICS OF AVIONICS EQUIPMENTS.

Self-explanatory.

DESIGN AND MANUFACTURING

WHAT THEY MEAN TO FLEET READINESS

MR. W. J. WILLOUGHBY, JR.

DEPUTY CHIEF OF NAVAL MATERIAL FOR RM&QA

During the following break you may stay to watch a videotape of Mr. Willis Willoughby. He will tell us the Navy's approach to handling the avionics integrity problems.

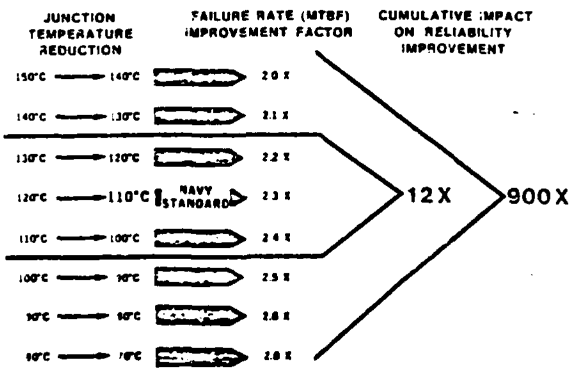
MATERIAL ACQUISITION FUNDAMENTALS

- MISSION PROFILE DEFINITION
- STRESS ANALYSIS
- DERATING CRITERIA
- WORST CASE ANALYSIS
- SNEAK CIRCUIT ANALYSIS
- PREDICTION/ALLOCATIONS
- FAILURE MODES & EFFECTS ANALYSIS
- TEST, ANALYZE, & FIX WITH CLOSED LOOP REPORTING
- DESIGN REVIEWS
- MISSION PROFILE QUALIFICATION TEST

* This is the route the Navy decided to go to achieve the operating life they wanted
* Reliability is a function of stress; if hardware is overstressed, it's not reliable.
* Analytical tools listed here have one purpose - to understand the stress in the hardware.
* If the tools are used correctly and rigorously, the data they produce is equaltoorbetter thansometest data.
* When using these tools, you aren't designing the most reliable piece of hardware.
  * Military has no requirement for long life equipment
  * The bulk of hardware is medium life reliability
  * There are analytical tools available to design no failure equipment (25 years, 35 years, etc)
  * These analytical tools were chosen because they are cost effective for achieving medium life reliability
* Everything on the chart is done by the contractor except the mission profile definition.

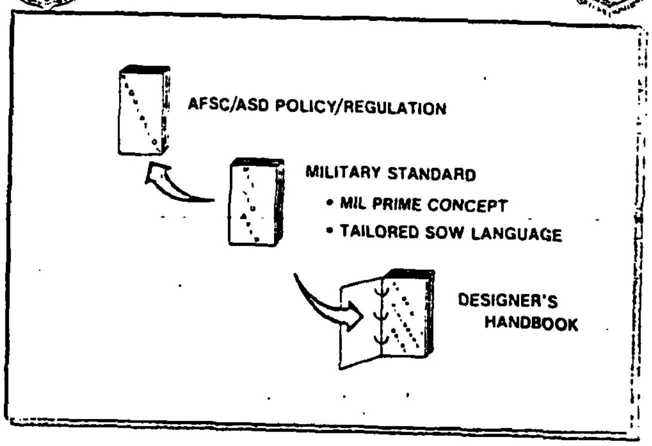
* The mission profile definition is the most important thing the program manager has to do.
  * If done right, the contractor has been given everything he needs.
  * If done wrong, the contractor has one hand tied behind his back.
  * The rest of the list doesn't really matter if the mission profile definition is wrong.
* Stress analysis is simple stress analysis that looks at the stress on the hardware.
* Derating criteria is determined from results of stress analysis. (If you intend to keep any equipment within certain stress profiles (determined in the stress analysis) it must be derated.
* Worst case analysis is done to make sure nominal conditions (previous analytical tool) are in the center of the analytical profile.
* Sneak circuit analysis is the stress that occurs due to unwanted current paths. (Unwanted current paths can be due to component failures, lifted bonds or switchology, interrelated paths that have not been planned.)
* Sneak circuit analysis shows you whether or not, in all cases, the current flow is as anticipated and there aren't any potential points where a single failure point can cause current to flow where you don't want it.
* This list must be done with discipline and rigor.

JUNCTION TEMPERATURE IMPACT ON SEMICONDUCTOR RELIABILITY



* A classic example of what you can gain by derating
* Between the junction temperatures of 150°C and 70°C, there is a 900X difference in reliability.
* The Navy chose 110°C as a good junction temperature.
* For every 10°C you derate the device, you double its life.
* With semiconductors there is a tremendous opportunity to improve the operating life of the equipment by paying close attention to junction temperatures.
* The world is evolving to junctions (next 5-10 years) and so, the most important thing you can manage is junction temperatures. (hybrid, chip, and card level)

DEFINING DOCUMENTS



These are the documents which will set forth what we need to do to improve integrity (military standard), what to do (designer's handbook), and who is to do it (AFSC or ASD regulation).

AVIP METHOD

DIVIDES THE LIFE CYCLE INTO FIVE STAGES

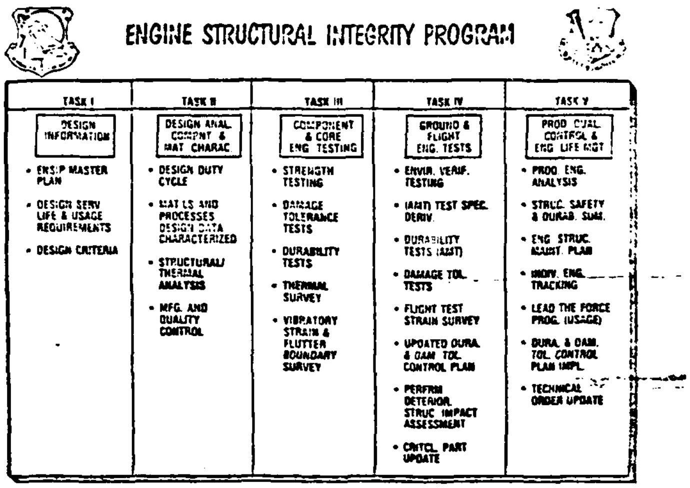
- I - DESIGN INFORMATION
- II - PRELIMINARY SYSTEM DESIGN
- III - DESIGN, ANALYSIS & DEVELOPMENT
- IV - COMPLIANCE, PRODUCTION & CONTROL
- V - FORCE MANAGEMENT

Self-explanatory.

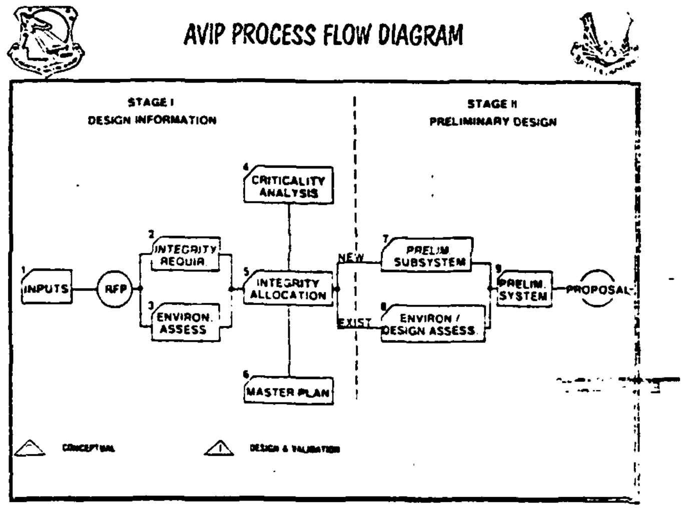
AVIP PROCESS TABLE (SYSTEM/SUBSYSTEM)

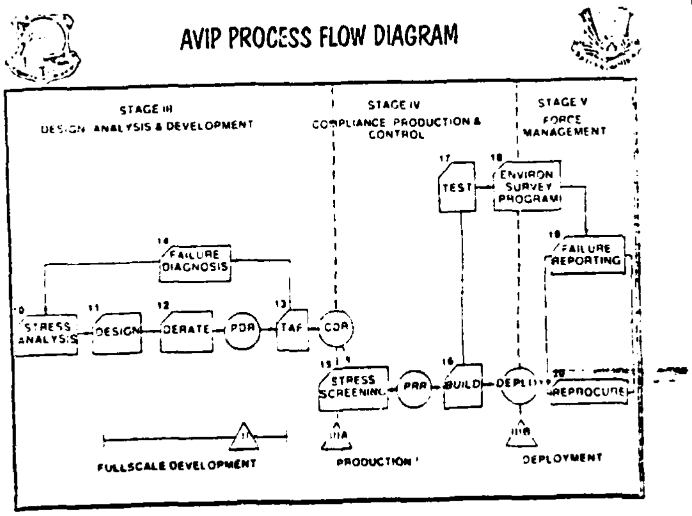
Stage I Design Information	Stage II Preliminary Design	Stage III Design, Analysis & Development	Stage IV Compliance & Production Control	Stage V Force Management
Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
1. Data Base 2. Integrity requmts Reliability Manufacturing Economic Life Maintain/Testability 3. Environ Assess (Mission Profile) 4. Historical Documnt (AIHD) 5. Sys Critical Anal 6. Integrity Allocate 7. Master Plan (AIMP) Environ Mgt Plan Thermal Mgt Plan System Safety Plan Reliability Plan Derating Plan Piece Part Screen Plan Stress Screen Plan Corrosion Plan Qual Assur Plan Warner Qual Prog Plan CAD/CAM Plan Manufacturing Plan Economic Life Plan Maintain Prog Plan Testability Prog Plan	1. Prelim Predict Anal Environ Rel Predict Manu/Produc Cost Pred Economic Life Predict Maintainability Pred 2. Environ Impact Assessment 3. Design Assessment 4. Manufacturing Assess 5. Prelim Sys Trades Sys Avail Prediction Supportability Anal	1. Stress Analysis 2. Environ Impact Assess 3. Design Computer Aid Design Reliability Predict 4. Failure Pred Anal FMECA Fault Tree Analysis Sneak Circuit Anal 5. Trades & Analysis Representative Models Thermal Management Producibility Economic Life Logistic Support Testability Design 6. Derating 7. Revised Install Req 8. Piece Part Control 9. Build Lab Prototype 10. Stress Screening 11. Test Anal & Fix 12. Failure Diagnostics FRACAS	1. Piece Part Control 2. Build Line Prototype 3. Stress Screening 4. Compliance Tests Laboratory Flight/Ground Qualification Reliability Qual Thermal Management Product Sampling Sys Eff Data Sys Testability Demo Acceptance 5. Environmental Survey 6. Build to Print 7. Process Control Manufacturing Control Computer Aid Manufacturing Product Readiness Review Component Source Control Assembly Control Workmanship Spec & Std Qual/Product Improvement Incoming Inspection Manufact Efficiency Prog	1. Data Base Warranty Life Supportability Data 2. Failure Reporting Sys Expanded Govm Data Sys Testability On Site Failure Test 3. Environmental Survey Prog 4. Reprocurement to Print

Self-explanatory, but note the correlation of this table to the next chart. Stages are equivalent to tasks.



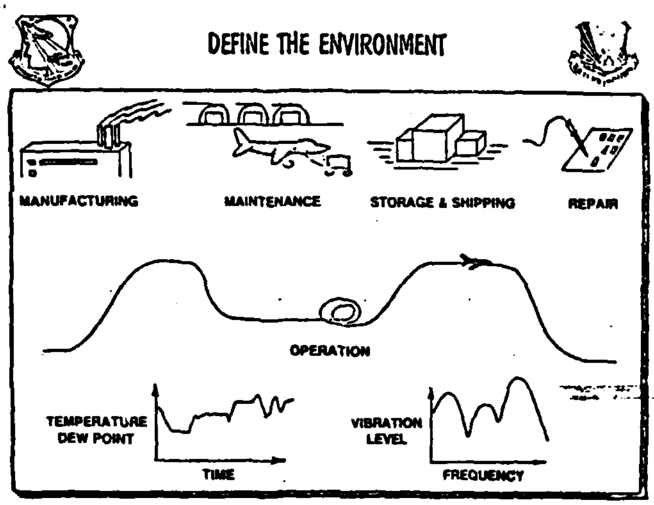
Self-explanatory.



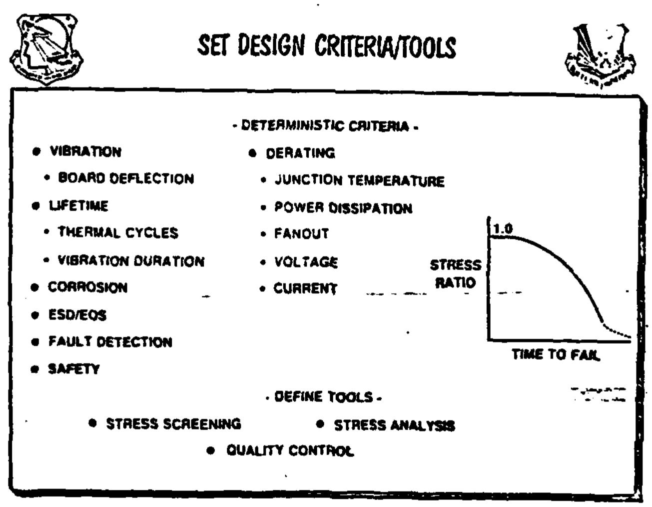


These two charts lay out the AVIP process table into a flow diagram. Note that the numbers at the upper left corner of the blocks refer to the activities which will be discussed through the rest of this tutorial. These activities will be indicated in the notes by the following notation:

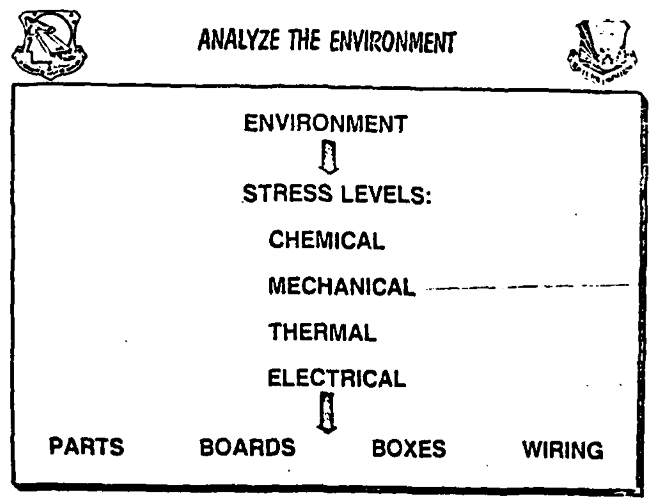
ACTIV # ___



ACTIV #1
The government must define the total environment for the integrator or manufacturer.

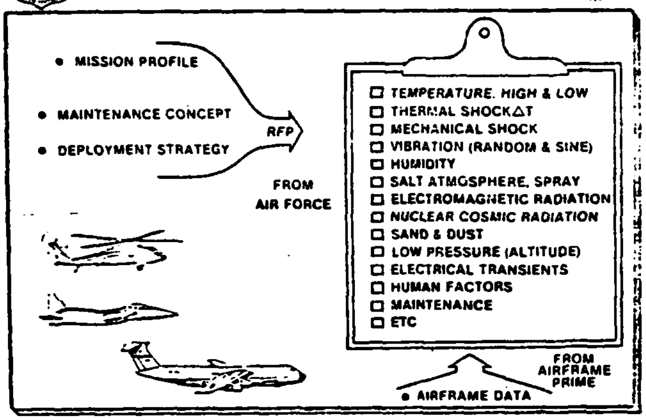


ACTIV #1
The government would establish the design criteria and point out the array of tools available to the manufacturer for use throughout the manufacturing process. Some of the design criteria and tools are listed here. Two key design criteria are the number of vibration cycles and the number of thermal cycles.



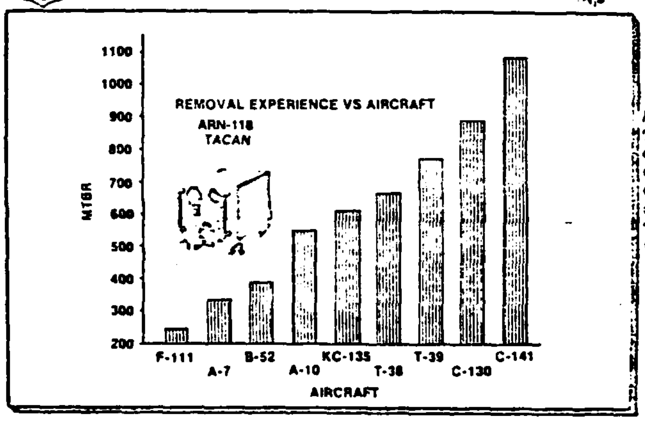
ACTIV #3
Next the manufacturer takes the more general requirements of the design criteria as set forth in the Request for Proposal (RFP) and establishes the specific environmental factors which his equipment will need to face in the field.

3. ENVIRONMENTAL ASSESSMENT



ACTIV #3
The integrator must then analyze the environment and determine the stresses which all the electronic equipment must face.

3A. ENVIRONMENTAL ASSESSMENT



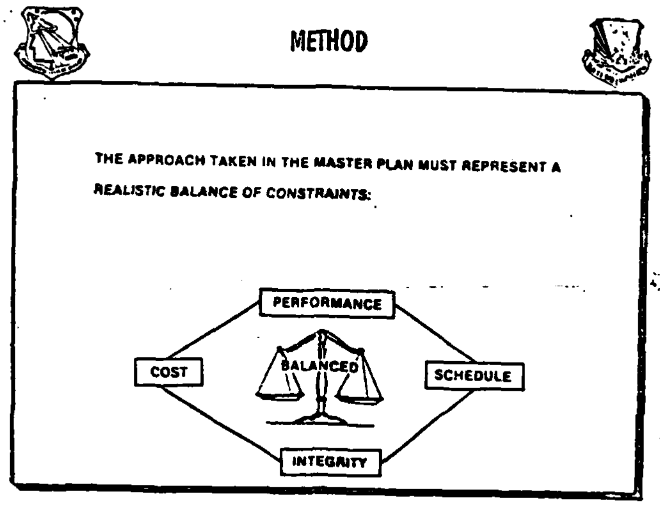
ACTIV #3
This graph shows the importance of establishing and analyzing the environment. The different aircraft environments on this graph yield different removal rates of the ARN-118 TACAN. This common item possesses a wide range of durability when exposed to different environments.

METHOD

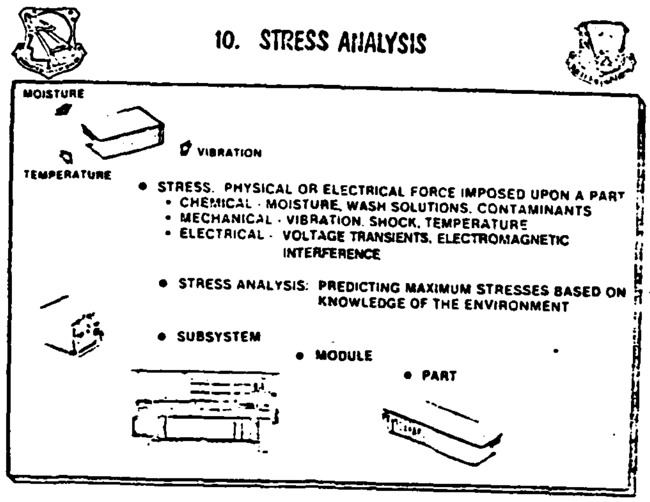
MASTER PLAN

- PREPARED BY MANUFACTURER
- DESCRIPTION OF APPROACH TO SATISFY INTEGRITY REQUIREMENTS
- SUBMITTED WITH PROPOSAL
- INCLUDES:
  - STRESS ANALYSIS
    - FATIGUE
    - CORROSION
  - THERMAL MANAGEMENT
  - DERATING
  - FAILURE DIAGNOSIS
  - TESTABILITY
  - STRESS SCREENING
- CONTRACTUAL

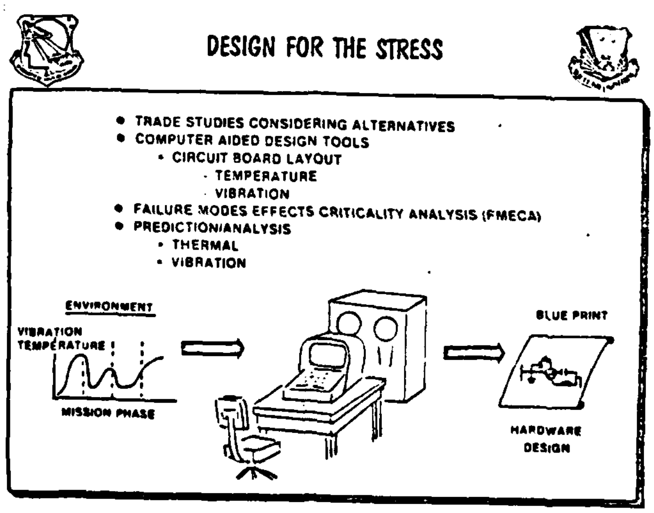
ACTIV #6
The master plan is most important in helping us to assure a quality product. It is submitted along with the proposal and becomes a part of the contract. It allows the manufacturer to tailor the integrity program to meet the requirements and fit his business structure.



ACTIV #6
The master plan, then, helps to assure that we have a balance between performance, cost, schedule, and integrity.



ACTIV #10
Stress analysis is very important. We need to define the expected stresses based on the environment. From this we can predict the expected lifetime of the particular piece of equipment.



ACTIV #11
With this stress analysis we can then design for the stress.

ELECTRONIC EQUIPMENT THERMAL MANAGEMENT

ACTIV #11
Mr. Robert Berger will now tell us about designing electronic equipment for thermal stress.

OUTLINE

- PROBLEM OVERVIEW
- *PROBLEM IDENTIFICATION*
- PROPOSED SOLUTION

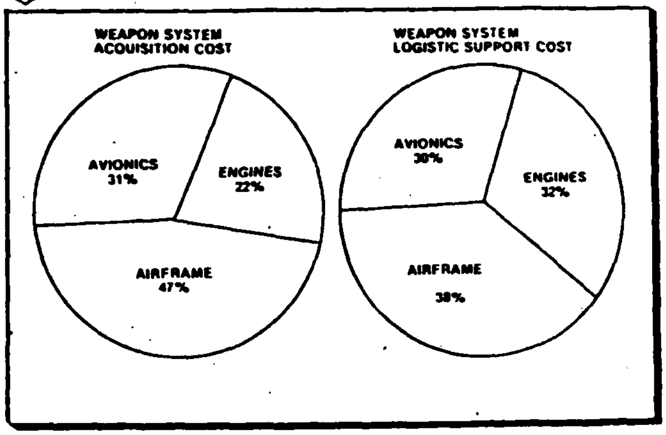
- OUTLINE - WILL PROVIDE SOME BACKGROUND, IDENTIFY THE PROBLEM WE ARE TRYING TO RESOLVE AND PROPOSE A PROGRAM TO RESOLVE THE PROBLEM.

BACKGROUND

• THERMAL MANAGEMENT SURVEY	AUG 81
• SYSTEMS APPROACH TO THERMAL MANAGEMENT	AUG 82
• INTRODUCED THERMAL MANAGEMENT CONTROL PROGRAM	JUL 83
• INTRODUCE ELECTRONIC EQUIPMENT THERMAL MGMT PROGRAM	JAN 84

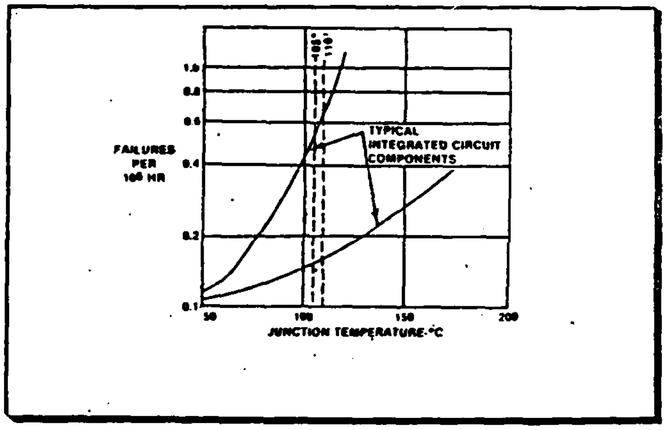
- BACKGROUND

LIFE CYCLE COST BREAKDOWN



- THE AVIONICS ACCOUNTS FOR ABOUT A THIRD OF A WEAPONS SYSTEMS ACQUISITION COST AND ABOUT A THIRD OF THAT SYSTEMS LCC. EVEN MINOR IMPROVEMENTS IN AVIONICS RELIABILITY OR LOWER LCCs CAN BE SIGNIFICANT.

AVIONICS RELIABILITY DEPENDS ON TEMPERATURE



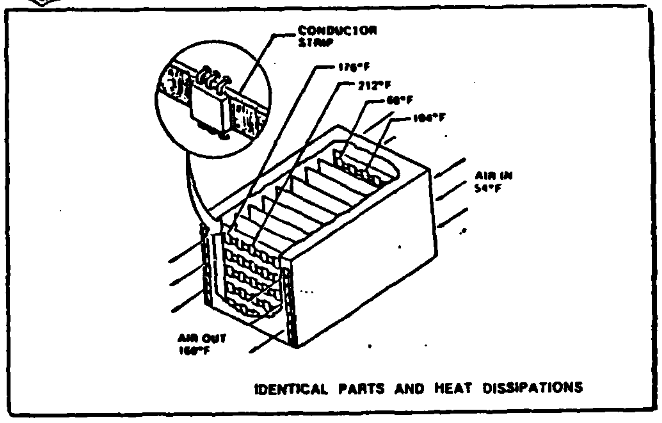
- THE RELIABILITY OF MANY ELECTRONIC PARTS IS A FUNCTION OF OPERATING TEMPERATURE. SOME PARTS ARE IMPACTED MORE THAN OTHERS BY TEMPERATURES.

REASON FOR COOLING

- MEET MINIMUM FUNCTIONAL PERFORMANCE
- MEET MINIMUM RELIABILITY REQUIREMENTS

- COOLING IS USED TO ATTEMPT TO CONTROL PART TEMPERATURES.

TYPICAL AIR COOLED AVIONIC UNIT



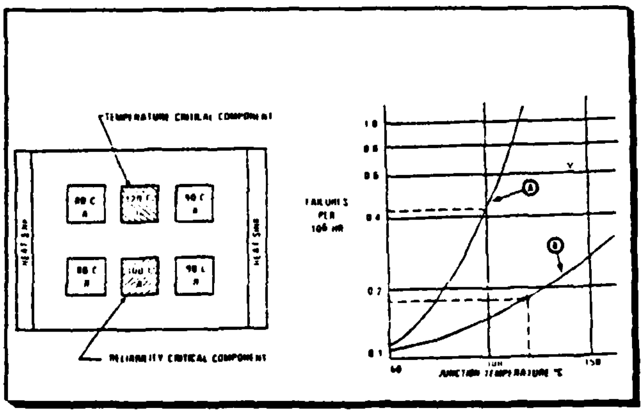
- EVEN WITH IDENTICAL PARTS WITH EQUAL HEAT LOADS, THE OPERATING TEMPERATURES DEPEND HEAVILY ON PART LOCATIONS AND COOLING PROVISIONS.

CURRENT "GOOD" DESIGN

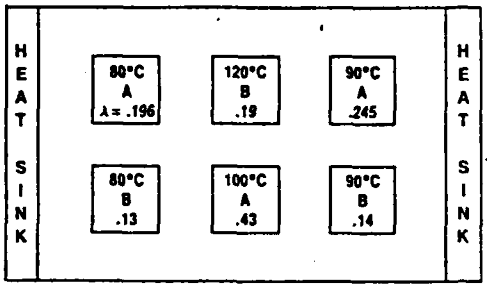
- DETERMINE PART OPERATING TEMPERATURES
- LOOK FOR "HOT SPOTS"
- LOOK FOR PART TEMPERATURES >105° C
- REDESIGN TO MEET ABOVE CRITERIA
- ENTER "TEST-ANALYZE-FIX" DO-LOOP

- GENERAL INQUIRIES INDICATED THAT THE STATE-OF-THE-ART AVIONICS EQUIPMENT DESIGN APPROACHES CONSISTED PRIMARILY OF THE FOLLOWING PRACTICES.

CURRENT THERMAL PRACTICE

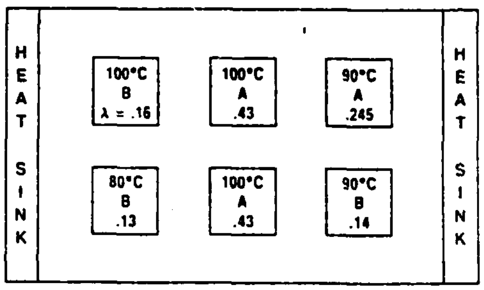


- APPLYING THIS APPROACH TO THE FOLLOWING SAMPLE CIRCUIT BOARD WITH TWO DIFFERENT COMPONENTS WITH FAILURE RATES DEFINED BY CURVE "A" AND "B" AS A FUNCTION OF JUNCTION TEMPERATURE. ANALYSIS OF TEMPERATURES VERSES RELIABILITY INDICATES TWO SEPARATE CRITICAL COMPONENTS.



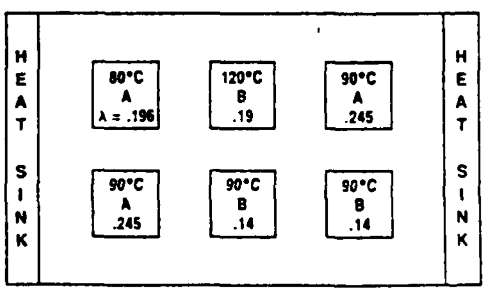
CASE I: BASELINE DESIGN WITH $\lambda_{BASE} = 1.331$

• CASE I - ASSUMING A SERIES CIRCUIT, CALCULATE A BASELINE FAILURE RATE λ OF 1.331. NOTE IF WE APPLY GOOD DESIGN PRACTICE DERATING REQUIREMENTS, "B" AT 120°C EXCEEDS 110°C LIMITS AND, THEREFORE, REDESIGN IS IN ORDER. SWITCHING "B" AT 120°C WITH "A" AT 80°C MEETS CRITERIA.



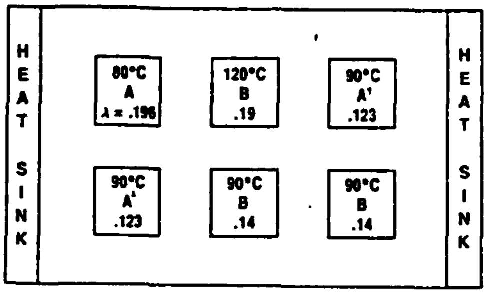
CASE II: MEET 110°C LIMIT - λ_{BASE} INCREASED 15%

• CASE II - INDICATES MEETING DERATING REQUIREMENTS DEGRADES RELIABILITY BY 15% IN THIS CASE BECAUSE CRITERIA WAS TO MINIMIZE TEMPERATURE RATHER THAN MAXIMIZING RELIABILITY.



CASE III: CONCENTRATE ON R DRIVER - λ_{BASE} DECREASED 13%

• CASE III - INDICATES NEED TO USE RELIABILITY AS DESIGN CRITERIA, NOT TEMPERATURE. "A" AT 100°C WAS RELIABILITY DRIVER. IF "A" AT 100°C IS SWITCHED WITH "B" AT 80°C, THERE IS A 13% IMPROVEMENT IN RELIABILITY. USING RELIABILITY NOW AS THE DESIGN CRITERIA, THERE ARE TWO COMPONENTS WHICH ARE THE RELIABILITY DRIVERS, THE TWO COMPONENT "A"s AT 90°C.



CASE IV : FURTHER DERATE R DRIVER (A') - λ_{BASE} DECREASE 21%

THIS LEADS US TO THE DEFINITION OF THE PROBLEM.

THE PROBLEM

- SYSTEM LEVEL -
  - COOLING NOT ALLOCATED TO:
    - MAXIMIZE A/C RELIABILITY ($\bar{R}$)
    - MINIMIZE A/C LIFE CYCLE COST (LCC)
- AVIONICS SUBSYSTEM LEVEL -
  - DURING CONCEPTUAL AND VALIDATION PHASES:
    - AVIONICS DESIGN IS NOT OPTIMIZED FOR $\bar{R}$ AND LCC
    - RELIABILITY INCORPORATED BY "TEST - ANALYZE - FIX"

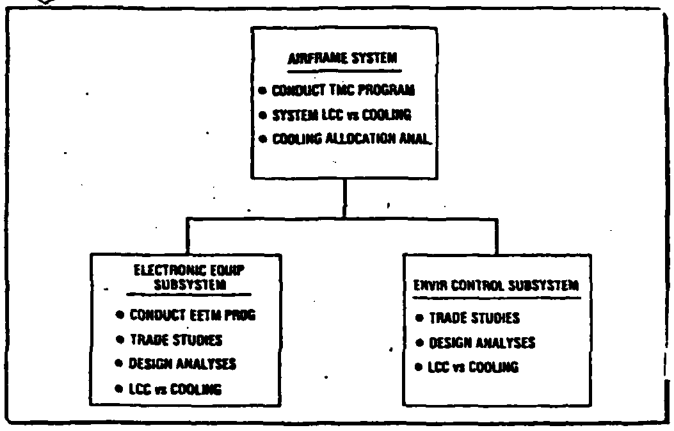
- CASE IV - SHOWS THE IMPACT OF "SELECTIVE DERATING WHERE "A^{1}" IS SUBSTITUTED FOR "A" AND THE BASELINE RELIABILITY IS IMPROVED BY 21%. LCC STUDIES STILL NEED TO BE CONDUCTED TO SEE IF THIS IMPROVEMENT IS COST EFFECTIVE AND, THEREFORE, ALL DESIGN CHANGES NEED TO BE EVALUATED IN TERMS OF LCC.

DEFINATION: THERMAL MANAGEMENT CONTROL (TMC)

THE THERMAL INTEGRATION OF THE ECS AND THE ELECTRONIC EQUIPMENT TO OPTIMIZE SYSTEM RELIABILITY ($\bar{R}$) AND MINIMIZE SYSTEM LIFE CYCLE COST (LCC)

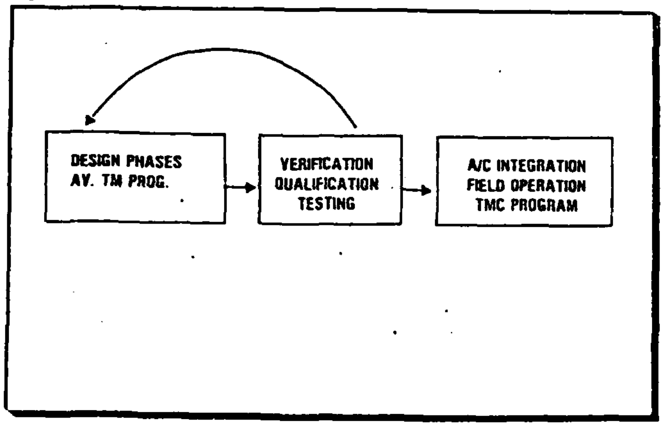
- THIS PROBLEM CAN BE EFFICIENTLY ADDRESSED THROUGH THE TMC PROGRAM.

THERMAL MANAGEMENT CONTROL PROGRAM



• TMC COVERS ACTIVITIES AT BOTH THE SYSTEM LEVEL AS WELL AS THE SUBSYSTEM LEVEL.

AVIONICS DEVELOPMENT PROCESS



• THE INTENT IS TO DESIGN IN RELIABILITY AS A PART OF THE INITIAL LAYOUT AND PACKAGING DESIGN RATHER THAN RELYING STRICTLY ON THE TEST-ANALYZE-FIX APPROACH. THIS IN NO WAY IS INTENDED TO REPLACE ANY OF THE PROVEN METHODS OF IMPROVING A PRODUCT'S RELIABILITY BUT TO SUPPLEMENT THESE METHODS AND HELP TO PRODUCE AN OVERALL BETTER PRODUCT IN THE END.

PROGRAM STATUS

- A. F. AVIONICS INSTALLATION STD - INCORPORATED
- CHANGES TO MIL-STD-785B - IN PROCESS
- DATA ITEMS FOR MIL-STD-785B - IN PROCESS
- PROGRAM DISSEMINATION - UNDERWAY

• CURRENTLY THE TMC PROGRAM IS BEING IMPLIMENTED UNDER VARIOUS PROGRAMS INCLUDING THE AVIP. THE FLOOR IS OPEN FOR QUESTIONS.

IMPROVING CORROSION RESISTANCE OF ASD AVIONIC SYSTEMS

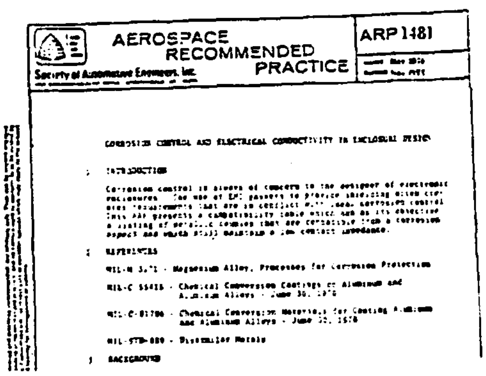
JOHN KAUFHOLD
AVIONIC INTEGRITY
ASD/ENAS

ACTIV #11
Now, Mr. John Kaufhold will discuss designing avionic equipment toavoid corrosion.

Roughly 35% of avionics failures can be traced to the effects of corrosion on the items. The corrosion is caused by the interaction of the environment with a) materials that are not designed to withstand the environment b) contaminations on the surfaces that interact to make corrosive agents that then interact to destroy the material integrity of the item, and c) poor engineering designs that provide for the accumulation of corrosive compounds.

ELECTROLESS NICKEL ON ALUMINUM

We have seen corrosion of connector backshells due to incompatibility between the base metal and the top-plating applied. A good instance of this is electroless nickel plating on aluminum as can be shown by Slide 2.


AEROSPACE RECOMMENDED PRACTICE | ARP 1481

Society of Automotive Engineers, Inc.

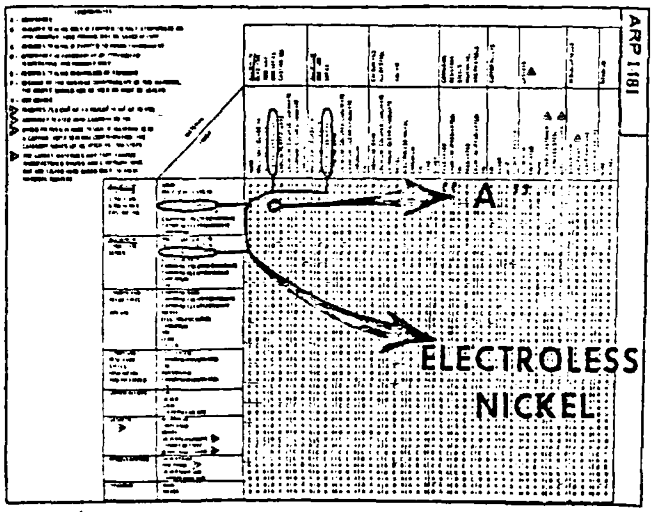
CORROSION CONTROL AND ELECTRICAL CONDUCTIVITY IN ENCLOSURE DESIGN

INTRODUCTION

REFERENCES

BACKGROUND

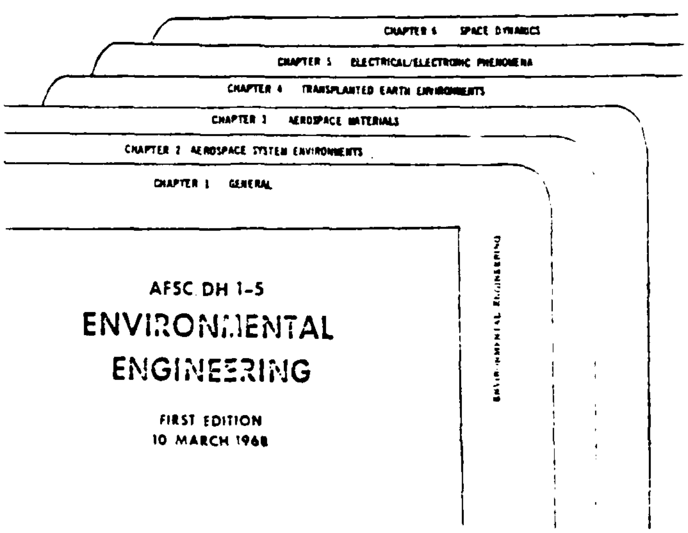
All services have experienced this problem. Yet the solution-elimination of nickel coating on aluminum is not forthcoming. It is often reinforced because of honest efforts to assemble and use a process document that looks good yet does not work well in fielded equipment. An example is the SAE Aerospace Recommended Practise ARP 1481 approved in November 1983, less than six months ago. (Slide 3). This document shows that nickel on aluminum is compatible. It is the use of documents like these, without knowing the environment they will be used in, that gets us into trouble.



ENVIRONMENTAL DESIGN THEOREM NO. 1

MOISTURE AND
CORROSIVE VAPORS WILL
GET IN AND ON ALL NON-
HERMETICALLY SEALED AVIONIC
EQUIPMENT IN DOD SERVICE.

To emphasize the impact that the environment has on equipment we have what we call environmental design theorem No. 1 (Slide 4). That is: "Moisture and corrosive vapors will get in and on all non-hermetically sealed avionic equipment in DOD service." This condition is especially critical when you realize that virtually all Air Force aircraft employs some form of ram-air cooling and the basic ambient environment impacts on much of the equipment. Until alternate environmental control systems are used, we will be subject to the problem of environmental Theorem No. 1 on all our avionics. The threat of chemical agents being used during war is also serious. They break down to form corrosive compounds to complicate our design for corrosion resistance.



We realize we have a problem - what tools are available to use to reduce or eliminate the problem? AFSC Design handbook 1-5 Environmental Engineering (Slide 5) has been available since 1968, yet it is not used or called out for use on our contracts and system specifications. It addresses all systems and environments, from ground to space, and corrosion prevention and control with respect to the environment.

NAVMAT P 4855-2

DESIGN GUIDELINES FOR PREVENTION AND CONTROL OF AVIONIC CORROSION

AVIONIC DESIGN RELATED TO FLEET ENVIRONMENT

TABLE 5-2 THE "DOs" OF EQUIPMENT DESIGN

"DOs"

- Design on the assumption that moisture and fluid will be present in the airframe and equipment.
- Seal all dissimilar metal (galvanic) couples
- Use parazylylene as a conformal coating on printed wiring boards
- Use an easily replaceable anodic (consumable) part in assembling grounding or bonding connections
- Electrically isolate graphite composite materials from avionic equipment
- Use only electrical connector boots that can be sealed with adhesives
- Carefully select a protective system for use on magesium
- Complete the working of aluminum (drilling, cutting, grinding) prior to surface treatment.
- Use surface treatments (anodize and conversion coatings) on aluminum
- Carefully select the metal plating used to provide sacrificial protection, barrier protection as a third metal between two otherwise incompatible metals, or as a substitute surface.
- Use a nickel strike under gold plating
- Use solder flux with lowest possible acid content
- Use metallic materials with the most corrosion resistant configuration (passivated) with minimum possible residual stressing
- Use fluorocarbon or fluorosilicone type materials for gaskets, "O" rings and seals.
- Seal conductive and EMI gaskets against moisture/fluid intrusion
- Use low point drains.
- Mount equipment and components at least ½ inch above potential standing water level.
- Use hermetic sealing where possible
- Use polysulfide sealants to seal non-pressurized equipment where moisture/fluid intrusion is possible
- Use transparent (clear) conformal coating
- Place ambient pressure sensing components outside equipment housings
- Design for maintainability
- Use shoe box lids.
- Mount PWBs vertically with the edge connectors on vertical edge or back of board
- Mount electrical connectors horizontally
- Use drip loops on electrical cables
- Use desiccant systems with visual indicators.
- Use cooling systems that remove moisture and particulate matter
- Use "O" rings to seal around control shafts that must penetrate an enclosure
- Be aware of various airframe interior and exterior fluids.
- Use electrical connectors with cork-and-bottle interfacial seals.
- Protect against insulative films
- Recognize the operational environment
- Recognize the maintenance environment
- Be aware of fleet maintenance procedures and materials
- Get the fleet maintenance technician's input
- Listen to feedback!

TABLE 5-3 THE "DON'Ts" OF EQUIPMENT DESIGN

"DON'Ts"

- Don't use dissimilar metal (galvanic) couples if it can be avoided.
- Don't use RTV that contains acetic acid
- Don't place graphite in contact with aluminum or any structural metal.
- Don't use heat shrink (non-sealed) electrical connector boots to stop moisture fluid intrusion.
- Don't mate magnesium to a metal more cathodic than aluminum.
- Don't use acrylic, RTV or varnish type conformal coatings
- Don't use gold over silver or copper
- Don't use organic materials that outgas, support fungi, absorb moisture or are degraded by maintenance and operational fluids
- Don't use silver, copper or graphite impregnated material for conductive or EMI gaskets
- Don't use top mounted lid fasteners
- Don't mount PWBs horizontally
- Don't mount electrical connectors (multicontact or coaxial) vertically.
- Don't place edge connectors on the bottom edge of a vertically PWB.
- Don't create side loads or cable tension on the rear seal of electrical connectors.
- Don't use direct air cooling on active electronic components
- Don't mount WRAs less than ½ inch above the compartment floor.
- Don't use hygroscopic materials
- Don't use nickel plated electrical connector shells.
- Don't use foam cushioning materials that can deteriorate (revert)
- Don't permit the presence of water lap areas

Do we have any specific military specification or standard that addresses corrosion prevention and control in the design of avionics equipment? NO. Ground support equipment has MIL-STD-808A. Aircraft have MIL-STD-1568 and 1587. Once deployed, we have logistic technical orders. No standard exists for the design. All services have this problem with electronics. The Navy has it especially bad because of the installation of aircraft on low freeboard ships, for example destroyers, and salt air and water around them in a hemispherical pattern when on sea maneuvers, for example, on a carrier. They have instituted a program where they have taken all their lessons learned and incorporated them into a document to be used during development of new system avionics. The document is NAVMAT, P 4855-2, titled: "Design Guidelines for Prevention and Control of Avionic Corrosion" (Slide 6). They require the use of the document in the contract statement of work and assess the design against the criteria specified therein. Since the document is "guidelines", the design criteria is shown as a list of "do's" and "don'ts". To give you some idea of the format, the next two viewgraphs (Slide 7) - DO's and (Slide 8) - DON'Ts are taken from the NAVMAT document.

ANATOMY OF AN ELECTRONIC BLACK BOX

1. MAKE SURE BOX CAN BREATHE IF NOT HERMETICALLY SEALED.
2. INSERT PRINTED CIRCUIT BOARDS IN THE VERTICAL POSITION.
3. LOCATE ELECTRICAL FEED-THRU CONNECTORS ON THE SIDE.
4. LOCATE CARD CONNECTORS ON SIDE OR BACK. NOT ON THE BOTTOM.
5. USE SIMILAR METALS ON CARD CONNECTORS AND PRINTED CIRCUIT BOARD CONTACTS.
6. DO NOT USE MATERIALS THAT MAY EMIT CORROSIVE VAPORS.
7. SEPARATE TO THE MAXIMUM EXTENT POSSIBLE POWER, RETURN, AND GROUND LEADS IN CONNECTORS AND PRINTED WIRING CIRCUITS.
8. MINIMIZE THE USE OF MAGNESIUM AND COPPER BEARING ALUMINUM FOR THE BASE STRUCTURE OF AVIONICS
9. ASSURE THAT ALL NON-HERMETICALLY SEALED AVIONICS BOXES HAVE DRAIN HOLES.

The other services also have aircraft in their inventory with avionics that have the same problems. The US Army Development and Readiness Command have taken their lessons learned and incorporated them into a package called the "Anatomy of an Electronic Black Box." The Viewgraph (Slide 9) shown here was taken bodily from the Army Handbook that supplements the Prevention of Material Deterioration: Corrosion Control Course presented by the Logistics Engineering Directorate at Rock Island, Illinois.

The basic elements shown are also distributed within the NAVMAT "Do's" and "Don'ts" lists. Because of the importance of these criteria, a short review of the rationale for them is warranted:

1. If the box cannot breathe and is not hermetically sealed (hermetic means gastight), thermal cycling of moisture laden air will allow water in but not out. Water will accumulate and fill the box. Ionic contaminants inside, either carried in by the gas or left as a result of the process, will become electrolytes that cause short circuit paths as the water level builds. The box function will be degraded or lost.

2. Moisture inside the box will condense due to thermal cycling. If the boards lie flat, water droplets can condense across circuit paths. If the boards are vertical, the condensation will run off. Also the heat generated through component operation will cause thermal currents that can self dry the boards.

3. Feed through connectors located on the bottom can have their rear surfaces equal to horizontal boards. Moisture can condense and flow into the recesses where the pins are. It can also seep down by the wiresleeving where it goes into the connector grommet. Electrolytic solutions will inevitably reach the electrically active pin surfaces and short across circuit paths and cause failure of the box.

4. Locating card connectors as indicated will eliminate the possibility of the bathtub effect of water covering the connectors and causing shorts. Because of the configuration of the card connectors, when bottom mounted, the rear active surfaces have the same effect as a horizontal board and are subject to the same conditions as item 2 of the previous viewgraph.

5. Dissimilar metals are a serious cause of corrosion and the loss of electrical continuity in avionics and electronic systems because of the inherent reactivity in the presence of an electrolyte. Use of similar metals will alleviate the problem.

6. The most commonly used wire sleeving is polyvinyl chloride. It is cheap and in a benign environment it is effective. However, when subject to heat, it decomposes to release hydrogen chloride gas. Chlorides are the most commonly found contaminant on avionics equipment. When hydrogen chloride mixes with water, it forms hydrochloric acid which in an enclosed environment will attack every open metal used in avionic systems and cause them to corrode. The corrosive by-products can become dielectrics that cause open circuits or bridge across circuit paths to cause shorts. Both cases cause loss of function on the Black Box.

7. This element is necessary because certain solder conditions cause dendrites to occur and bridge circuit paths. If the power paths are adjacent to each other, shorts will occur with very little dendrite growth and destroy the power feed path or connector power feed pin. This situation is also present if an electrolyte droplet falls across two adjacent power leads. Using this criteria will require much greater amounts of dendrites or electrolytes for the shorts to occur. The amount required may never be reached if this design criteria is used.

8. Magnesium and copper bearing aluminum is used where lightweight and high strength are desired. The higher the strength of these alloys, the more they are susceptible to corrosion. Avionic structures do not normally need to be super high strength or superlight.

9. Remember item 1 said design the box to breathe. A box can breath if it has louvers high up. Yet it can still have a bathtub effect if there is no solution outlet. Collection of water will create the carrier for corrosive electrolyte formation. The drain is therefore required.

THE ANATOMY OF AN ADEQUATE DRAIN HOLE

1. DRAIN HOLE MUST BE LOCATED IN THE LOWEST PORTION OF THE AREA TO BE DRAINED.

2. DRAIN HOLE MUST BE LARGE ENOUGH FOR WATER TO RUN OUT.

3. DRAIN HOLE MUST BE LARGE ENOUGH TO ALLOW DEBRIS TO BE REMOVED WITH THE WATER.

4. DRAIN HOLE MUST BE LARGE ENOUGH TO ALLOW A PROTECTIVE COATING TO BE APPLIED TO THE WALLS OF THE DRAIN HOLE.

Because of the importance of a drain hole, a correctly designed one is required to perform as intended. Therefore, from the same Army handout we have the "Anatomy of a Drainhole" (Viewgraph 11). The following rationale shows the importance of paying attention to detail on something often perceived as mundane. The key is understanding the materials properties of the elements that interact to affect the operation of a drainhole.

1. *If the drainhole is not in* the lowest portion, the "bathtub effect" will still occur and electrical components in the box will become subject to corrosion and short circuits. The attitude of the box in both flight and ground storage must be considered when locating the drain hole(s).

2. If the drain hole is too small, the surface tension of the entrapped fluid will not allow it to flow out and the "bathtub effect" will be reinforced.

3. If the hole is too small, corrosive by products developed may plug the hole and create the bathtub effect.

4. If the drain hole is not protected, the electrolyte can cause the development of corrosion by-products that reduce the drain hole diameter and subsequently plug the drain hole or reduce it such that surface tension of entrapped liquid allows the bathtub effect to occur and cause shorts in the box. This development of the drain hole provides an example of the thought process and attention to detail that is required for selection of materials, design, and engineering processes required to develop avionic systems that meet Air Force mission requirements.

WHAT ARE WE DOING - ENA

- Developing corrosion prevention and control requirements for the Avionics Integrity MILPRIME standard.
- *Identifying state-of-the-art materials and packaging configurations to be included in the MILPRIME handbook.*
- Addressing the EMI compatibility and corrosion prevention simultaneous requirements with the AFWAL/ML program.

ADDITIONAL SUGGESTIONS

- ADD SPECIFIC GUIDELINES TO RFPs
- EVALUATE PROPOSALS IN SOURCE-SELECTION AGAINST THE GUIDELINES
- ASSIGN CORROSION TRAINED AVIONICS ENGINEERS TO CPABs
- PROVIDE THE AFALC TAILORED CORROSION AND PREVENTION LESSONS LEARNED PACKAGE AS PART OF THE RFP PACKAGE

What are we doing at ASD to instill corrosion resistance in our avionics? We are addressing it as a requirement in the Avionics Integrity Program by incorporating it as shown (Viewgraph 12). Of particular interest is the last bullet because of apparently conflicting requirements of present designs. This is illustrated by the electroless nickel example referenced earlier in the presentation.

CORROSION CONTROL FOR AVIONICS

— Who to contact

ASD MONITOR FOR THE USAF CORROSION PROGRAM
JOHN GOODMAN ASD/ENFSS 55471

ENA FOCAL POINT FOR AVIONICS CORROSION CONTROL
JOHN KAUFHOLD ASD/ENAS/AVIP 53369

AFWAL TECHNICAL MANAGER FOR CORROSION CONTROL
BENNIE COHEN AFWAL/MLSA 55108

AFWAL AVIONIC CORROSION PROBLEMS
GEORGE SLENSKI AFWAL/MLSA 53487

We can use the following additional suggestions (Viewgraph 13) to enhance the program. We plan to use the NAVMAT philosophy to develop the first two bullets. From a corrosion control viewpoint, we would like to see contractors assign materials engineers to review and approve electronic design and manufacturing processes and to the corrosion prevention advisory board (CPAB's) shown in bullet 3. Materials of bullet 4 can be provided in a sanitized version with any request for proposal (*RFP*). *At ASD, the cognizant people* in Avionic Corrosion are the following (Viewgraph 14).

VERIFY DESIGN

- ANALYSIS
  - DRAWING VERIFICATION
- TEST
  - EFFECTIVE IN PRECIPITATING OUT FAULTS BEFORE THE SYSTEM IS DEPLOYED
  - APPLICATION OF INCREASINGLY COMPLEX ENVIRONMENTS
    - *COMBINED ENVIRONMENT RELIABILITY TESTING (CERT)*
  - TEST TO OBTAIN FAILURE & IMPLEMENT FIXES
- DESIGN REVIEWS

ACTIV #13
A test, analyze, and fix program can be used to assure the design is going to be effective in the expected environment.

AVIONICS INTEGRITY PROGRAM

FAILURE DIAGNOSIS

21 MAY 1984

DR. BILL DOBBS
AFWAL / MLSA
WPAFB, OH

ACTIV #13
Dr. Bill Dobbs will now discuss failure diagnosis which could be used in a test, analyze, and fix program.

- FAILURE DOCUMENTATION
- RESEARCH DEVICE CHARACTERISTICS
- INDEPTH COMPONENT ANALYSIS
- ESTABLISH FAILURE MODE
- CORRECTIVE ACTION

* Self-explanatory.

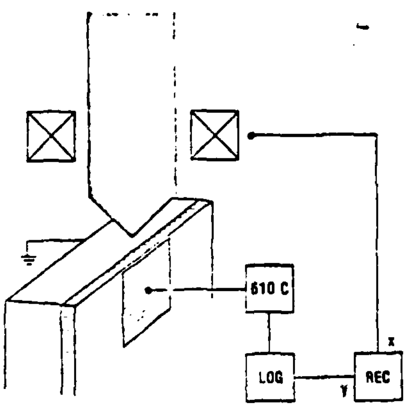
ELECTRONIC FAILURE ANALYSIS

- o SEM & TEM
- o SURFACE ANALYSIS
- o CHEMICAL ANALYSIS
- o CERT
- o SAMPLE MOUNTS
- o ANGLE LAPPING
- o THERMOGRAPHY
- o LIQUID CRYSTALS
- o IR MICROSCOPE
- o PIND
- o WIRE BOND PULL TESTER
- o PROBE STATION & ELECTRICAL TEST

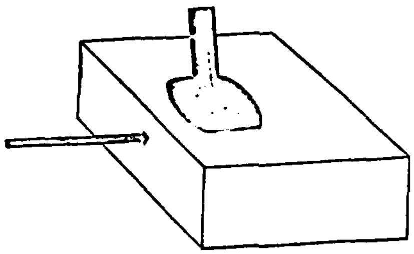
* List of electronic failure analysis techniques.

* The next two viewgraphs are photographs of two instruments used in electronic failure analysis
* The first viewgraph shows an engineer using an optical microscope to examine a failed integrated circuit
* The second viewgraph shows a specimen being placed in the scanning electron microscope

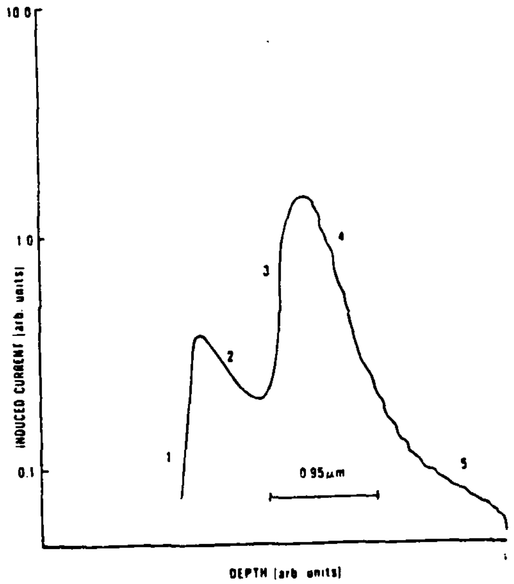
(Not shown in notes)



* Scanning electron microscope (SEM) used to measure electron beam induced current (EBIC) in semiconductor device
* Semiconductor sample is placed in the SEM and the sample current is measured by the logarithmic amplifier before it is displayed on the x-y plotter.
* Dark arrow represents electron beam.
* Provides information on the minority carrier diffusion length.

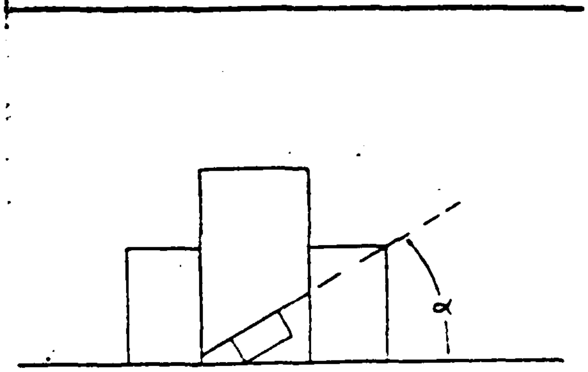


* Shows how the electron beam strikes the sample



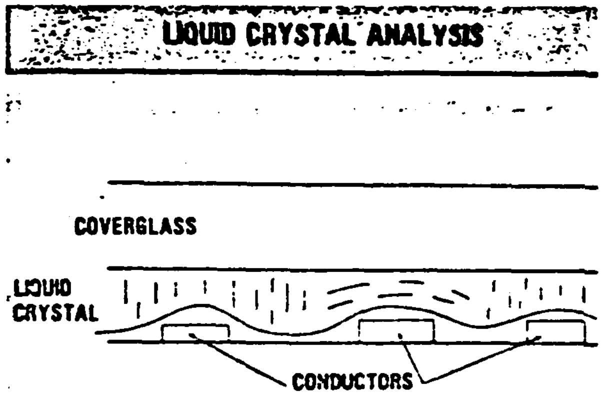
* Output curent vs depth in EBIC sample

ANGLE LAPPING



* Angle lapping of failed device which is mounted at the angle α
* Sample polished at small angle (enlarges and exposes regions below the substrate surface)
* Semiconductor is stained to establish the different p-type and n-type regions
* Angle lapping permits the measurement of diffusion depths or ion implanation depths

* A photograph is presented showing an angle lapped sample (microwave transistor)



* Liquid crystal analysis shows use of nematic liquid crystals to identify active circuit elements
* The circuit is viewed through the cover glass with polarized light
* Liquid crystals above a biased conductor are oriented differently than those above an unbiased material
* Polarized light shows difference in crystal orientation

* The next two viewgraphs are IR microscope images of a CMOS capacitor - the first is a top view and the second is a bottom view

(Not shown in notes)

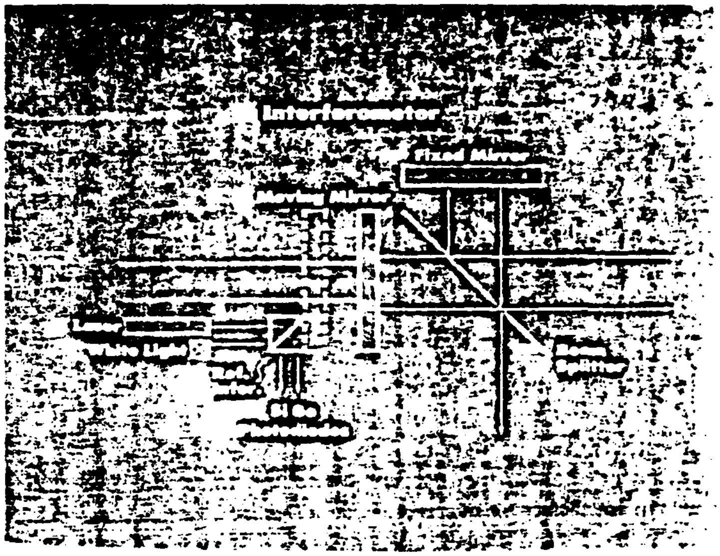
* The next viewgraph is a photograph showing nailheading and a crack in the inner conductor foil of a plated through hole in a PWB

(Not shown in notes)

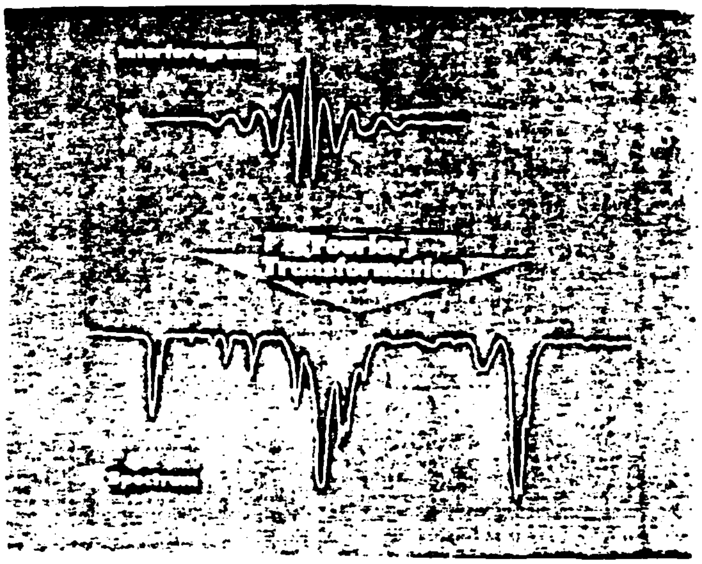
CHEMICAL ANALYSIS METHODS

- INFRARED, VISIBLE & ULTRAVIOLET ABSORPTION
- RAMAN SPECTROSCOPY
- X-RAY DIFFRACTION
- ATOMIC ABSORPTION
- GAS & LIQUID CHROMATOGRAPHY
- MASS SPECTROMETRY
- WET CHEMICAL & MICROELEMENTAL ANALYSES

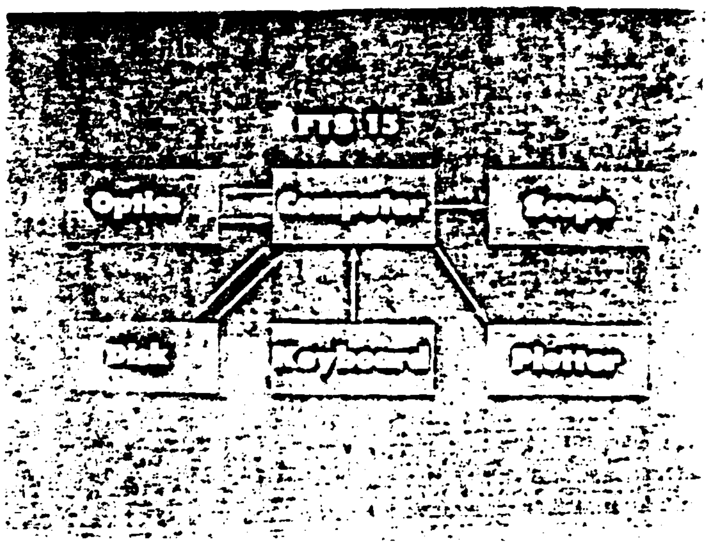
* Methods of chemical analysis which are used in electronic failure analysis



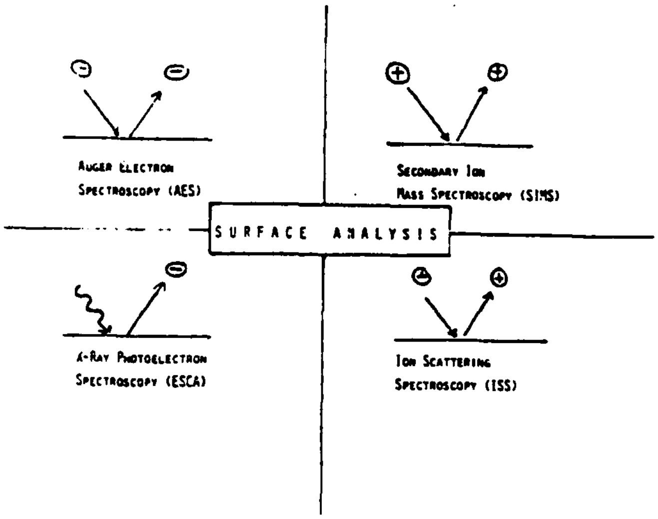
* Shows a schematic of an interferometer used in Fourier transform spectroscopy



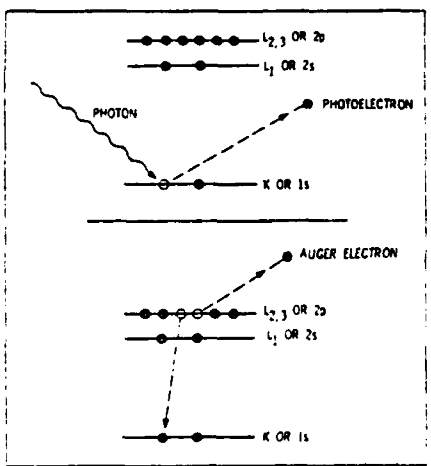
* Shows Fourier transform spectrum obtained from interferograms



* Addresses the computer and equipment used to make the Fourier transform in the previous viewgrapn
* Infrared absorption allows the collection of useful data from very weak signals and results in quick and accurate data reduction



* Surface analysis techniques used for the detection of contamination or any changes associated with a thin atomic layer
* Schematic representation of four surface analysis techniques
* Illustrates the interaction of the excitation beamwith the surfaceunder examination



* Description of the Auger and photoelection processes

SURFACE ANALYSIS TECHNIQUES

ADVANTAGES	DISADVANTAGES
ISS	
GOOD SENSITIVITY	PEAK OVERLAP
MAPPING	CONSUMES SAMPLE
SEMI-QUANTITATIVE	ROUGHNESS SENSITIVE
TOP LAYER SENSITIVE	MATRIX EFFECTS
	NO CHEMICAL INFO
SIMS	
ALL ELEMENTS	STRONG MATRIX EFFECTS
HIGH SENSITIVITY	CONSUMES SAMPLE
CHEMICAL INFO	PEAK OVERLAP
SEPARATES ISOTOPES	ORIENTATION ROUGHNESS SENSITIVE
MAPPING	
ESCA	
MOST ELEMENTS	SLOW
CHEMICAL EFFECTS	NO ISOTOPE SEP
SEMI-QUANTITATIVE	H He EXCLUDED
MINIMAL SAMPLE DAMAGE	NO MAPPING LARGE AREA
AES	
FAST	E-BEAM
MAPPING	SENSITIVITY > 01%
MOST ELEMENTS	NO ISOTOPE SEPARATION
CHEMICAL EFFECTS	H He EXCLUDED
SEMI-QUANTITATIVE	PEAK OVERLAP
METALS INSUL. SC	
NOT CONSUMING	

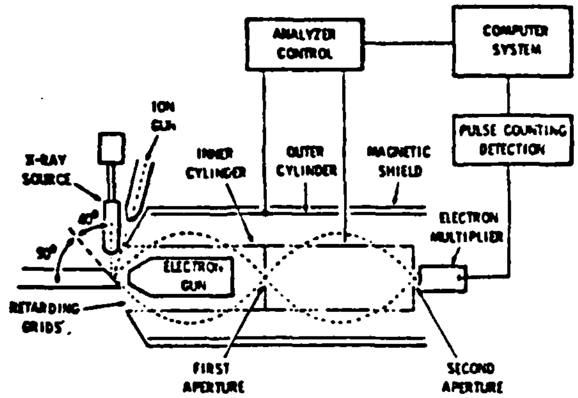
* A comparison of surface analysis techniques

SURFACE ANALYTICAL TECHNIQUES

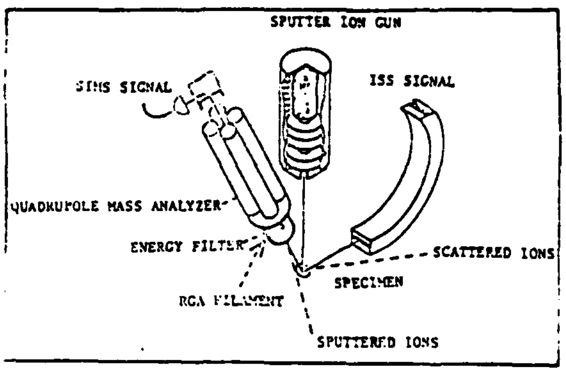
	QUAL. ANAL	QUANT ANAL	CHEM BONDS
AUGER ELECTRON SPECTROSCOPY	A	B	C
X-RAY PHOTOELECTRON SPECTROSCOPY	A	B	A
SECONDARY ION MASS SPECTROSCOPY	A	C	B
ION SCATTERING SPECTROSCOPY	B	A	C

A - Very Good
B - Useful
C - Fair to Poor

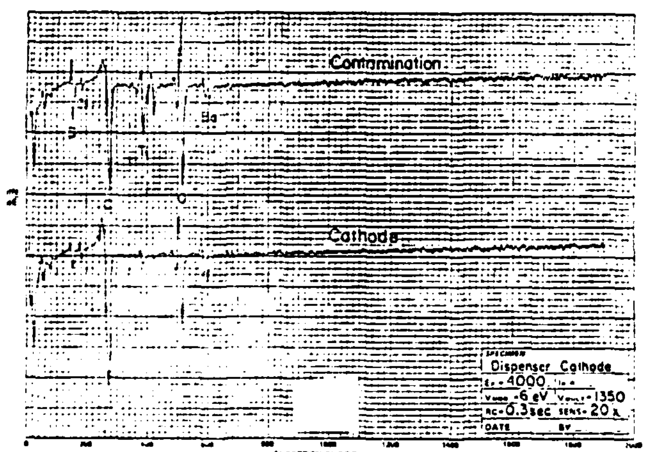
* A comparison of surface analysis techniques



* A schematic representation of instrument used for AES and ESCA



* A schematic representation of instrument used for ISS and SIMS



* Shows Auger signal from a cathode
* The top curve is for a contaminated cathode
* The bottom curve is for a cathode that isn't contaminated

* The next two viewgraphs are in reference to the previous viewgraph (Auger signal from a cathode)
* The first shows Auger maps of an oxide cathode
* The second shows Auger maps of a contaminated cathode

(Not shown in notes)

MAJOR SOURCES OF ELECTRONIC FAILURE

* IMPROPER MATERIALS SELECTION
* MANUFACTURING PROCESS DEFICIENCIES
* INADEQUATE SPECIFICATIONS

* Self-explanatory.

* The next three viewgraphs concern a certain failure analysis project
* The first viewgraph contains a photo of a munition
* The printed circuit boards are separated by a polyvinyl chloride (PVC) vibration dampening foam
* Mechanically the dampening foam worked well but chemically the foam released chlorides which collected on the printed circuit boards in the device
* The transistor failures were traced to chloride contamination and small amounts of moisture caused severe corrosion of the chloride contaminated printed circuit board
* The second viewgraph shows a chloride contaminated transistor from the munition (dark areas represent where it was burned)
* The third viewgraph shows a PWB from the munition with chloride contamination from foam

(Not shown in notes)

* The next viewgraph is a photo of a PWB contaminated with corrosion products which short out the circuits
* This unit was received new from the manufacturer, stored for nine months, biased, and identified as a failed part
* During manufacturing, solder flux residues contaminated the board and weren't adequately cleaned from boards before conformal coating
* With the addition of a small amount of moisture, entrapped contaminates easily caused corrosion

(Not shown in notes)

* The next two viewgraphs concern a gallium arsenide diode that was failing at a high rate
* The first viewgraph shows the chip sitting on a header and the light area on top is a gold contact
* The chip was pressed into silver loaded, conductive epoxy
* The viewgraph shows a cross-section of the chip
* It shows how the conductive epoxy was flowing around the diode edges and shorting out the p-n junction
* It was determined that more care was needed in placing the diode in the epoxy

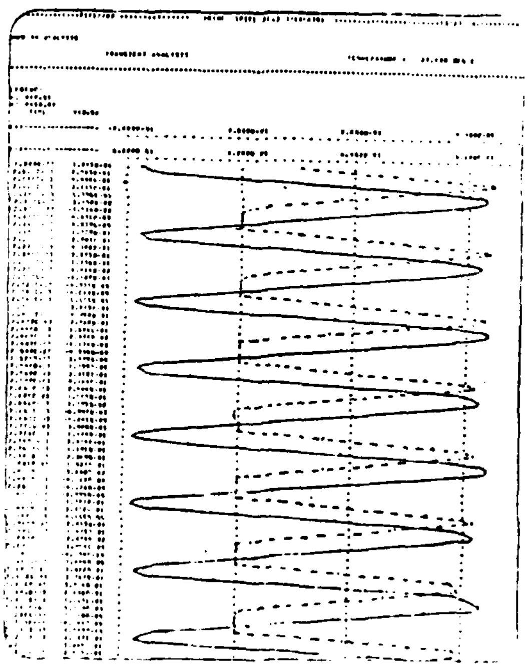
(Not shown in notes)

* The next two viewgraphs concern a hybrid package that contained 4% moisture
* The first viewgraph shows the hermetically sealed package
* The package passed a fine leak test - indicates the moisture was sealed in during manufacturing
* The second viewgraph shows the gross corrosion on one of the IC's in the hybrid

(Not shown in notes)

* The next two viewgraphs show a failed power supply that had potted modules soldered onto the motherboard
* Poor potting procedures caused solder cracks in the modules
* In a redesign, the modules will be conformally coated

(Not shown in notes)



* Example of computer aided transient analysis of a circuit
* Accomplished with the SPICE program, a general purpose circuit simulation program developed by the University of California
* Allows data to be collected or hypothesis examined in ways that are impractical experimentally

* The next four viewgraphs concern a potted module
* The first viewgraph is an x-ray of the potted module and shows the IC package
* The second and third viewgraphs both show the exposed IC and it can be seen that it's of off-shore vintage
* The fourth viewgraph shows the IC with the lid removed and shows excessive bonding

(Not shown in notes)

* The following four viewgraphs show a thin film chromium resistor
* The first viewgraph shows a failure in the resistor (arrow)
* The second viewgraph shows a failure in the resistor that occurred at the corner (arrow)
* The failure was caused by electromigration of the chromium into the aluminum
* The third viewgraph is an optical shot with the arrows marking contamination that's visible through the glass coating on the resistor
* The fourth viewgraph points out the same two failures as the third viewgraph
* Glass was removed from the resistor in the photo
* High package moisture content and contamination accelerated the failure

(Not shown in notes)

CONCLUSIONS

- IMPROPER MATERIALS SELECTION, MANUFACTURING PROCESS DEFICIENCIES AND INADEQUATE SPECIFICATIONS ARE RESPONSIBLE FOR 83% OF THE ELECTRONIC FAILURES
- ELECTRONIC FAILURE ANALYSIS IS A HIGH PAYOFF AREA - A KEY TO IDENTIFYING AND CORRECTING DEFICIENCIES
- CORRECTIVE ACTION COST IS USUALLY LOW FOR MANUFACTURER - ROI IS USUALLY HIGH FOR AIR FORCE
- PRODUCT ASSURANCE IN ELECTRONICS NEEDS EMPHASIS

* Self-explanatory.

CONTROL FABRICATION

MANUFACTURING TOOLS

- STATISTICAL QUALITY CONTROL
- IN-PROCESS INSPECTION
  - SAMPLES
  - MANUAL DATA BASE
  - TRACK TENDENCY TO DRIFT
- DIRECT PROCESS CONTROL
- ON-LINE INSPECTION
  - 100%
  - AUTOMATED DATA BASE/DATA LINKS
  - REAL TIME CONTROL
- EARLIER IN-PROCESS CONTROLS
  - STRESS SCREENING
  - FAILURE DIAGNOSIS
    - PEOPLE (WORKMANSHIP)
    - PARTS (MATERIALS)
    - PROCESSES
    - DESIGN
- FAILURE FREE ACCEPTANCE TEST

ACTIV #15
Self-explanatory.

STRESS SCREENING

HEAD UP DISPLAY SYSTEM STRESS SCREENING

MARCONI AVIONICS LTD., ROCHESTER, ENGLAND

YEAR	TOTAL PARTS SCREENED	TOTAL DEFECTIVE	% DEFECTIVE	COST OF SCREENING	COST OF NOT SCREENING: ASSUME 5-% FOUND AT CARD	ASSUME 25% FOUND AT UNIT	TOTAL
1980	1,800K	14.8K	.82	174.6K	280.5K	807.5K	1,088K
1981	1,730K	15.5K	.89	215.3K	292.8K	842.9K	1,136K

YEAR	SAVINGS	RATIO
1980	913K	4.6:1
1981	920K	3.9:1

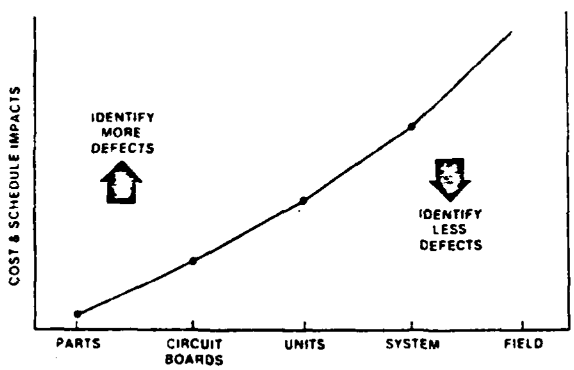
PARTS: HIGH RELIABILITY COMPONENTS MIL-M-38510 LEVEL B
SCREEN: MIL-STD-883 GROUP A TEST

*A. J. Dane, "Profitability of Planning for Stress Screening," IES 1983 Proceedings, 29th Annual Meeting, 19-21 April 1983

ACTIV #15
Here is an example to show the effect that stress screening at the lowest level of assembly can have on manufacturing cost. Marconi Avionics LTD definitely experienced a savings. Note that the money figures are in English pounds.

1

ESSEH IS EFFECTIVE



NAECON 84

PHILLIP H HERMES
ASD/YYE! (X56845)

ACTIV #15
Mr. Phillip Hermes will now explain why environmental stress screening (ESS) is effective.

(2)

OVERVIEW

- ESSEH EFFECTIVENESS
- TRADITIONAL FAILURE DISTRIBUTIONS
- CONCEPTUAL APPROACHES TO ESSEH
  - PARTS
  - CIRCUIT BOARDS
  - UNITS/SYSTEMS
- STATEMENT OF WORK APPROACH
- SUMMARY

SELF EXPLANATORY

(3)

ESSEH TEST EFFECTIVENESS
96 MISSILE GUIDANCE SECTIONS

CIRCUIT BOARD TEST CATEGORIES	% GUIDANCE SECTIONS THAT FAILED: 13 CIRCUIT BOARDS PER GUIDANCE SECTION	FUNCTIONAL CHECKS AT ROOM TEMP	PRODUCTION RELIABILITY ACCEPTANCE TESTS
• UNSCREENED	NA	18	18
• TEMP CYCLING			
10°C/MINUTE	20	12	18
20°C/MINUTE	38	7	9
POWER ON	33	11	11
OFF	18	5	11

NOTES:
- CANNOT ACHIEVE 20°C/MIN AT UNIT OR SYSTEM SCREENS
- CIRCUIT BOARD SCREENS PRIMARILY USED TO STIMULATE LATENT DEFECTS
- UNIT/SYSTEM LEVEL SCREENS PRIMARILY USED TO CHECK PERFORMANCE

- THIS TEST WAS DESIGNED TO EVALUATE ESS TEST EFFECTIVENESS AT THE CIRCUIT BOARD LEVEL OF ASSEMBLY.
- GROUPS OF 13 CIRCUIT BOARDS WERE EXPOSED TO NO SCREENS AND TO DIFFERENT TYPES OF SCREENS.
- THE NO SCREEN CATEGORY WAS THE "CONTROL" CATEGORY, WHICH REPRESENTS TRADITIONAL MILITARY REQUIREMENTS.
- THE RESULTS INDICATE THAT:
  - 20°C/MIN TEMPERATURE RATES ARE TWICE AS EFFECTIVE AS 10°C/MIN IN STIMULATING LATENT DEFECTS AT THE CB LEVEL OF ASSEMBLY.
  - 20°C/MIN HAS THE MOST COST EFFECTIVE DISTRIBUTION OF DEFECTS FOR A PRODUCTION PROGRAM (38-7-9).
  - CIRCUIT BOARD POWER "ON" IS TWICE AS EFFECTIVE AS POWER "OFF" AT THE CB LEVEL.
  - UNIT OR SYSTEM LEVEL FUNCTIONAL CHECKS OR SCREENS ARE MORE EFFECTIVE FOR EXPANDED PERFORMANCE CHECKS THAN FOR STIMULATING LATENT DEFECTS. THUS, THE EMPHASIS SHOULD BE TO STIMULATE LATENT DEFECTS AT THE LOWER LEVELS OF ASSEMBLY AND CHECK PERFORMANCE AT THE HIGHER LEVELS OF ASSEMBLY.
- THIS TEST WAS DESIGNED TO SEPARATE THE EFFECTS OF DIFFERENT SCREENS FROM A STATISTICAL VIEWPOINT. IT ALSO INCLUDED CB EXPOSURE TO 6, 12, 24, AND 48 THERMAL CYCLES, WITH 24 CYCLES FOUND TO BE MOST COST EFFECTIVE. THE CB TEMPERATURE EXTREMES WERE -40°C TO +75°C.
- CB SCREENS REDUCED FIELD RETURNS BY 4:1.

(4)

ESSEH COST EFFECTIVENESS - EQUIP. SYSTEM "A"

	CIRCUIT BOARDS	UNITS	SYSTEM	FIELD
• TEST COST/ITEM	$0.69	$262	$4,600	NA
• FIX COST/DEFECT	$68	$246	$1,506	$4 000
• DEFECTS/EQUIV SYSTEM	48 (586 CBs)	19 (27 UNITS)	4	NA

<u>COST PENALTY/SYSTEM FOR NOT CONDUCTING CB SCREENS</u>

- CIRCUIT BOARD SCREEN = NO
  - DELETE CB TEST COST $0.69 X 586 = $404
  - DELETE CB FIX COST $68 X 48 = <u>$3,264</u>

TOTAL COST REDUCTION: $3,668/SYSTEM

UNIT SCREEN = YES, 50% EFFECTIVE
- ADD UNIT FIX COST $246 X 24 = $5,904
- ADD FIELD FIX COST $4 000 X 24 = <u>$96 000</u>

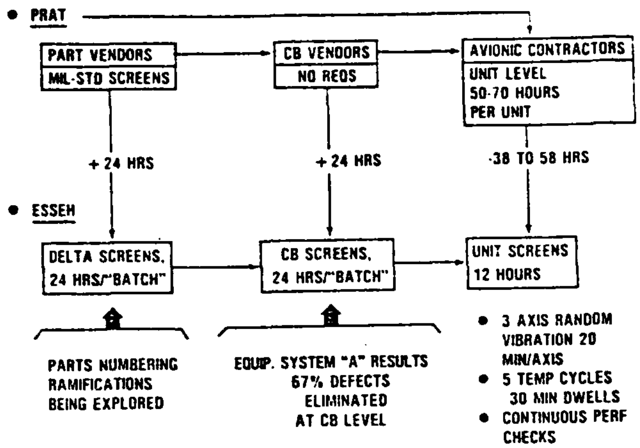
TOTAL COST INCREASE: <u>$101,236/SYSTEM</u>

COST PENALTY: $98,236/SYSTEM

- EQUIPMENT SYSTEM "A" IS A COMPLEX AIRCRAFT RADAR SYSTEM WITH 27 LRUS, 586 CIRCUIT BOARDS, AND 47,302 ELECTRONIC PARTS.
- 435 SYSTEMS WERE PRODUCED DURING 1972-79.
- THE PRODUCTION COST FIGURES WERE DEVELOPED BY A STUDY OF MANHOURS CONSUMED AT $23/HR.
- CIRCUIT BOARD SCREENS, 46 THERMAL CYCLES, -60°C TO +95°C, 15°C/MIN, POWER OFF.
- ANYONE CAN "WORK-THE NUMBERS" IN THE BLOCKS TO DETERMINE THEIR OWN MEASURE OF ESS COST EFFECTIVENESS.
- THE EXAMPLE GIVEN ASSUMES THAT UNIT LEVEL SCREENS ARE ½ AS EFFECTIVE AS CIRCUIT BOARD SCREENS IN <u>STIMULATING LATENT DEFECTS</u> (UNIT AND SYSTEM SCREENS WILL ALWAYS "PICK UP" PERFORMANCE ANOMALIES NOT DETECTED AT THE CIRCUIT BOARD LEVEL).
- ON THE OTHER HAND, UNIT AND SYSTEM LEVEL SCREENS CANNOT ACHIEVE THE COST EFFECTIVE TEMPERATURE RATES (15°C TO 20°C/MIN) <u>TO STIMULATE LATENT DEFECTS</u>.
- IT SHOULD BE NOTED THAT CIRCUIT BOARD SCREENS PROVIDE "REAL-TIME" PRODUCTION COST AND SCHEDULE SAVINGS FOR THE CONTRACTORS; AS WELL AS LONG-TERM COST SAVINGS, AND IMPROVEMENTS IN MISSION EFFECTIVENESS, FOR THE MILITARY SERVICES.

ESSEH SCHEDULE EFFECTIVENESS

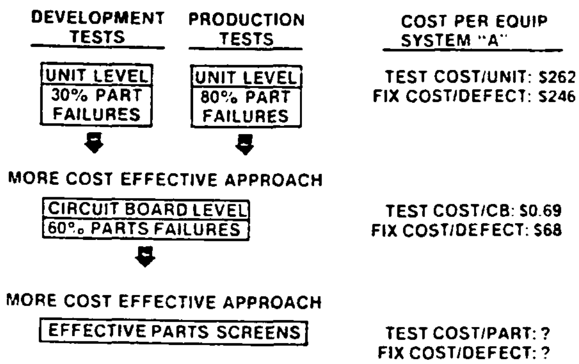
(5)



- THE TEST TIMES SHOWN ARE TEST TIME REQS. THEY DO NOT INCLUDE "DOWN-TIME" FOR CORRECTIVE ACTIONS.
- ESSEH IS VERY COMPATIBLE WITH PRODUCTION SCHEDULES SINCE MOST OF TEST TIME IS DONE AT THE LOWER LEVELS OF ASSEMBLY AT VARIOUS SUBCONTRACTORS PLANTS WITH VERY LITTLE TEST TIME SPENT AT THE AVIONIC CONTRACTORS PLANT AT THE FINAL ASSEMBLY LINE. IN OTHER WORDS TESTING IS DISPERSED AT VARIOUS LOCATIONS WHICH MEANS THAT TESTING CAN BE DONE CONCURRENT RATHER THAN SEQUENTIAL.
- THIS APPROACH ALSO MAKES EACH MANUFACTURER RESPONSIBLE FOR ITS OWN QUALITY LEVEL.
- IT IS NOT UNUSUAL TO HAVE PRAT REPLACED BY ESSEH IN THOSE CASES WHERE PRAT IS INCOMPATIBLE WITH PRODUCTION SCHEDULES.
- ESSEH IS EVEN MORE SCHEDULE EFFECTIVE THAN PRAT WHEN YOU CONSIDER THE "DOWN-TIME" DUE TO CORRECTIVE ACTIONS AT THE UNIT LEVEL OF ASSEMBLY, SINCE ESSEH HAS ALREADY IDENTIFIED & ELIMINATED MOST OF THE DEFECTS AT THE LOWER LEVELS OF ASSEMBLY.
- AN ASD/AFALC/DESC AD HOC GROUP IS PRESENTLY WORKING THE PIECE PART SCREENING ISSUE. THE MOST LIKELY OUTCOME WILL BE TO INCLUDE THE DELTA SCREENS IN THE MIL-STD SCREENS.

TRADITIONAL FAILURE DISTRIBUTIONS

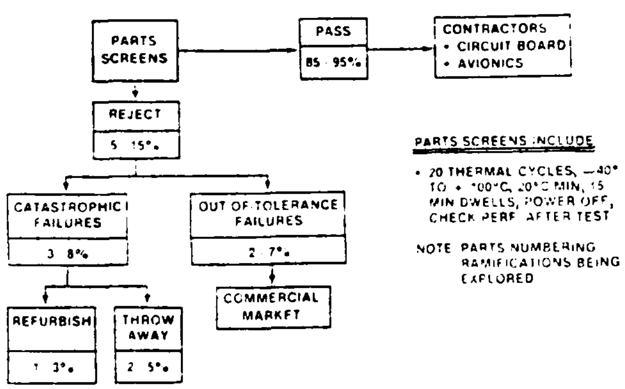
(6)



- IF WE FOLLOW THE TRAIL" OF THE FAILURE CATEGORY "PIE CHARTS" THROUGH THE LEVELS OF ASSEMBLY, IT IS NOT DIFFICULT TO CONCLUDE THAT SIGNIFICANT IMPROVEMENTS CAN BE MADE IN ESSEH BY IMPROVING THE ELECTRONIC PIECE PART SCREENS, ESPECIALLY FOR MICROELECTRONIC DEVICES & DISCRETE SEMICONDUCTORS.
- FINDING PARTS DEFECTS AT HIGHER LEVELS OF ASSEMBLY COST THE CONTRACTORS & THE AIR FORCE MORE MONEY THAN NECESSARY TO ACHIEVE PROGRAM OBJECTIVES.
- ALSO, APPLYING ESSEH TO HARDWARE SCHEDULED FOR DEVELOPMENT TESTS WILL SIGNIFICANTLY REDUCE THE COST & SCHEDULE IMPACTS FOR THESE TESTS, AND IT WILL PROVIDE THE CONTRACTORS WITH AN EXPERIENCE BASE TO SUPPORT THE DEVELOPMENT OF A PRODUCTION ESSEH PROGRAM.

CONCEPTUAL APPROACH TO PARTS SCREENS

(7)



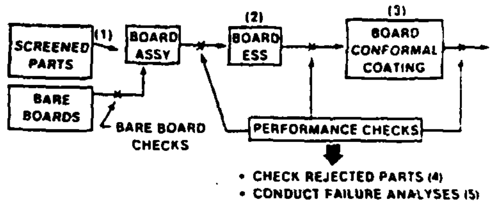
PARTS SCREENS INCLUDE

- 20 THERMAL CYCLES, −40° TO +100°C, 20°C/MIN, 15 MIN DWELLS, POWER OFF, CHECK PERF AFTER TEST

NOTE: PARTS NUMBERING RAMIFICATIONS BEING EXPLORED

- THERE SHOULD BE MANY DIFFERENT APPROACHES TO ESSEH AND THESE APPROACHES SHOULD BE CONSTANTLY CHANGING, BASED ON "LESSONS-LEARNED" AND ON THE INTRODUCTION OF NEW PART DESIGN APPROACHES.
- ON THIS VG & THE FOLLOWING 2 VGs, I WILL REVIEW ONE OF MANY POSSIBLE APPROACHES TO ESSEH AT THE PARTS, CIRCUIT BOARDS, AND UNIT/SYSTEM LEVELS OF ASSEMBLY.
- THE DISTRIBUTIONS IN THIS VG ARE BASED ON VARIOUS LITERATURE SOURCES. THE DISTRIBUTION BETWEEN "CATASTROPHIC FAILURES" AND "OUT-OF-TOLERANCE" FAILURES IS TYPICALLY 50%/50%.
- OF PARTICULAR NOTE IS THE POSSIBILITY OF MINIMIZING THE COST OF PART REJECTS (I.E., ONLY 2-5% OF TESTED PARTS ARE THROWN AWAY). IT SEEMS THAT A BUSINESS STRATEGY IS REQUIRED, TO MINIMIZE THE COST OF PART REJECTS, WHICH IS ACCEPTABLE TO ALL PARTIES.
- ANOTHER UNIQUE ANOMALY WITH PARTS SCREENS IS THAT "BAD" LOTS OCCUR INFREQUENTLY, AND IN A RANDOM FASHION. A "QUICK-REACTION" DATA, MANAGEMENT, & ENGINEERING SYSTEM IS REQUIRED TO EFFECTIVELY ADDRESS THIS ANOMALY.

CONCEPTUAL APPROACH TO CIRCUIT BOARD SCREENS



NOTES

(1) DEVELOP "QUICK-REACTION" SYSTEM FOR INFREQUENT LOT PROBLEMS

(2) ESS: 20 THERMAL CYCLES, —40° TO + 100°C, 20°C/MIN, 15 MIN DWELLS, POWER OFF, CHECK PERF AFTER TEST

(3) ESS SUGGESTED PRIOR TO CONFORMAL COATING TO SIMPLIFY DEFECTIVE PART REMOVAL WHILE MAINTAINING COATING INTEGRITY

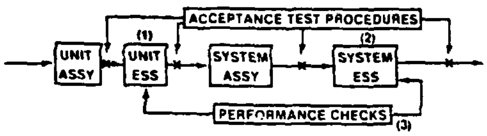
(4) PAST ANOMALY: 50% OF REJECTED PARTS CHECKED OUT "GOOD" AT PART LEVEL CHECKS

(5) FAILURE ANALYSES IS CRITICAL TO PROBLEM SOLUTION. BUT IT IS SELDOM DONE ADEQUATELY IN A PRODUCTION ENVIRONMENT

8

- THE CIRCUIT BOARD AND AVIONICS CONTRACTORS ALSO NEED A "QUICK-REACTION" SYSTEM TO EFFICIENTLY ADDRESS RANDOM LOTS OF "BAD" PARTS, WHICH OCCUR ON AN INFREQUENT BASIS
- ANOTHER IMPORTANT SCREENING ACTIVITY IS TO CHECK THE BARE BOARDS FOR OPENS/SHORTS AND FOR INSULATION RESISTANCE AMONG THE IMBEDDED CIRCUITS. ALSO CHECK FOR DELAMINATION.
- PERFORMANCE CHECKS SHOULD BE ACCOMPLISHED AFTER
  - BOARD ASSY - TO IDENTIFY DEFECTS GENERATED BY BOARD ASSEMBLY PROCESS
  - BOARD ESS - TO IDENTIFY DEFECTS SURFACED BY ESS
  - CONFORMAL COATING - TO IDENTIFY DEFECTS SURFACED BY HIGH TEMP DURING PROCESS (CONFORMAL COATING IS A THERMAL SCREEN)
- A CRITICAL PART OF THE CB SCREENING PROCESS IS TO CHECK THE PERFORMANCE OF THE INDIVIDUAL PARTS. AFTER THEY HAVE BEEN IDENTIFIED AS BEING DEFECTIVE DURING THE CB PERFORMANCE CHECKS. PARTS IDENTIFIED AS DEFECTIVE AT THE CIRCUIT BOARD LEVEL, WHICH ARE LATER FOUND TO BE GOOD AT THE PART LEVEL, CAN QUICKLY INCREASE SCREENING *COST IF THIS ANOMALY IS NOT HIGHLIGHTED AND CORRECTED.*
- PARTS IDENTIFIED AS DEFECTIVE AT THE CB AND PART LEVEL SHOULD UNDERGO EXTENSIVE FAILURE ANALYSES (MATERIAL LAB. ETC.) TO DETERMINE THE FAILURE MODES. THIS ACTIVITY IS ESSENTIAL TO PROBLEM RESOLUTION. THIS ACTIVITY MAY BE THE WEAKEST LINK IN THE CONTRACTORS CB SCREENING APPROACH. THIS WEAKNESS IS ALSO RELATED TO FEEDBACK INFORMATION TO THE PARTS VENDORS AND TO THE LACK OF CONTRACTOR AGREEMENT AMONG CONTRACTORS TO ADDRESS FAILURE ANALYSES AND CORRECTIVE ACTION RESPONSIBILITIES. THIS WEAKNESS IS REFLECTIVE OF CONTRACTORS REACTION TO MIL-STD REQUIREMENTS WHICH ARE LIMITED TO "GO"/"NOGO" SCREENING CRITERIA.

CONCEPTUAL APPROACH TO UNIT/SYSTEM SCREENS



NOTES

(1) UNIT ESS
- 3 AXIS RANDOM VIBRATION, 20-800 HZ, $0.04G^2$/HZ, 20 MIN/AXIS
- 5 THERMAL CYCLES, MAX CHAMBER TEMP RATES, MAX EQUIP. COOLING RATES, —40° TO +71°C CHAMBER TEMPS, CONTINUOUS PERF CHECKS, 30 MIN. DWELL TIMES, LAST *TWO CYCLES FAILURE FREE.*

(2) SYSTEM ESS: TEMP CYCLING SAME AS UNIT ESS

(3) LEVEL OF PERFORMANCE CHECKS IS IMPORTANT. NEEDS TO BE *BETWEEN BIT & APT WITHIN PRACTICAL MEASUREMENT* CONSTRAINTS NEED DATA SYSTEM TO RELATE RESULTS AT ALL LEVELS OF ASSEMBLY

- WITH THE EXCEPTION OF THE RANDOM VIBRATION TESTS AT THE UNIT LEVEL OF ASSEMBLY, THE UNIT & SYSTEM SCREENS ARE PRIMARILY PERFORMANCE CHECKS WHICH ARE MOST EFFECTIVE AT THESE LEVELS OF ASSEMBLY.
- THE LEVEL OF PERFORMANCE CHECKS IS VERY IMPORTANT HERE. THIS IS WHY FULL ATPs SHOULD BE PERFORMED BETWEEN STEPS AND THE LEVEL OF PERFORMANCE CHECKS DURING THE ESSEH SHOULD BE MAXIMIZED (BEYOND BIT) TO THE EXTENT WHICH IS PRACTICAL.
- 3 AXES OF RANDOM VIBRATION ARE REQUIRED SINCE VIBRATION FAILURE MODES ARE *AXIS DEPENDENT.*
- 0.04 G^2/HZ IS CONSIDERED A REASONABLE LEVEL OF VIBRATION, AND IT IS FAR MORE EFFECTIVE THAN $0.02G^2$/HZ (REF: GRUMMAN STUDY). ALTHOUGH ONE AVIONIC EQUIP HAD PROBLEMS WITH THIS LEVEL (DETAILS UNKNOWN).
- THE -40°C LIMIT WAS SELECTED SINCE MANY ELECTRONIC PARTS WILL NOT "START UP" AT -54°C, AND SINCE A STUDY OF CLIMATIC DATA INDICATES THAT A -40°C VALUE WILL "COVER" THE WORST CASE TEMP VALUES FOR MOST OF THE WORLD.

SOW APPROACH
ENVIRONMENTAL STRESS SCREENING OF ELECTRONIC HARDWARE

- OBJECTIVE
- HARDWARE SCOPE
  - AIRBORNE ELECTRONICS (NEW OR MAJOR MODS)
  - MICROELECTRONICS & SEMICONDUCTORS
- FSD ACTIVITIES TO DEVELOP ESSEH
  - STUDIES
  - VENDOR INTERFACES
  - RESULTS OF FSD TESTS (FAILURE MODES)
  - EXPERIMENTS (EXPLORE ALTERNATIVES)
  - FSD BASELINE ESSEH (DEFINE IN SOW) ➡
  - PROPOSE PRODUCTION APPROACH (FOR PROCURING ACTIVITY APPROVAL)
- *PRODUCTION ESSEH ACTIVITIES*
  - IMPLEMENT INITIAL PROCEDURES
  - IMPLEMENT DATA SYSTEM
  - REVISE PROCEDURES AS NECESSARY

APPLY TO HARDWARE FOR

- ENVIRONMENTAL QUAL
  - VIBRATION
  - TEMP/ALTITUDE
  - HUMIDITY
- TAF
- RELIABILITY QUAL

10

- THE KEY TO A CONTRACTUAL ESSEH APPROACH IS TO PROVIDE EXTENSIVE "LEARNING" REQUIREMENTS IN THE FULL-SCALE DEVELOPMENT (FSD) PHASE.
- FROM A CONTRACTUAL VIEWPOINT, AN FSD BASELINE HAS TO BE WRITTEN IN THE SOW TO GET ANY MEANINGFUL ESSEH RESPONSE OUT OF THE "CORPORATE" CONTRACTOR (CONTRACTOR ENGINEERS ARE NOT THE DECISION MAKERS). THE EXCEPTION IN THIS CASE, THOUGH, IS THAT THE FSD BASELINE ESSEH IS NOT JUST AN ADD-ON COST ACTIVITY, BUT RATHER, IT CAN SIGNIFICANTLY REDUCE THE DEVELOPMENT TEST COSTS AND SCHEDULE IMPACTS BY ELIMINATING PIECE PART & WORKMANSHIP FAILURES IN THE HARDWARE SCHEDULED FOR THESE DEVELOPMENT TESTS. THUS, THE DEVELOPMENT TESTS WILL NOT HAVE SIGNIFICANT COST & SCHEDULE PENALTIES TYPICALLY ASSOCIATED WITH PIECE PART & WORKMANSHIP FAILURES.
- AT THE END OF FSD, THE CONTRACTOR SHOULD PROVIDE A COST EFFECTIVE TEST PLAN FOR PRODUCTION ESSEH, BASED ON "LESSONS-LEARNED", FOR PROCURING ACTIVITY REVIEW AND APPROVAL.

SUMMARY

- ESSEH IS EFFECTIVE
  - TEST
  - COST
  - SCHEDULE
- 15-20°C/MIN TEMP RATES ARE CRITICAL
  - PIECE PARTS
  - CIRCUIT BOARDS
- FSD ESSEH ACTIVITIES ARE CRITICAL TO THE CONTRACTORS TO
  - GAIN ESSEH EXPERIENCE
  - REDUCE COST & SCHEDULE IMPACTS/DEVELOPMENT TESTS
- ESSEH DATA TRACKING SYSTEMS ARE IMPORTANT TO
  - PROVIDE "EARLY WARNING" OF RANDOM LOT PROBLEMS
  - INTEGRATE RESULTS AT VARIOUS LEVELS OF ASSEMBLY

SELF EXPLANATORY

NOTE: EXTENSIVE ESSEN REFERENCE MATERIAL CAN BE OBTAINED FROM THE:
INSTITUTE OF ENVIRONMENTAL SCIENCES
940 E. NORTHWEST HWY
MT PROSPECT, IL 60056
(312) 255-1561

MILITARY CHALLENGE TO INDUSTRY

- AVIONICS MUST DELIVER 2000-HOUR MTBF
- DEFECTIVES MUST BE REMOVED AT THE LOWEST PART LEVEL
- BUILT-IN TEST SHOULD BE LESS THAN 10% OF ELECTRONIC PACKAGE
- 10% LOGISTIC SUPPORT CAN BE A REALITY

ACTIV #16
During the next break Dr. Joe Capitano will tell us why ESS has been effective for Gould, Inc.

* All avionics must be a 2000 hour system
* Inexpensive method: force fail parts at *lowest level of assembly*
* If force fail parts at the lowest level and manufacture quality products then built-in-test need be only 10% of the package.
* 2000 hour MTBF is a 4 year failure free product so don't really need BIT testing.
* 10% logistics support is possible; If services don't change their ways, Gould may have to put defectives back in so maintenance people can stay proficient in repair of the equipment.

ANALYTICAL QUALITY TOOLS

DEFECT ANALYSIS AND CORRECTIVE ACTIONS ELIMINATE FUTURE FAILURES

FOR EACH PROBLEM AREA, "TEST" OR ASSESS

TO DETERMINE AREA OF ORIGIN

- DESIGN •PARTS/MATERIAL •PEOPLE •PROCESS

FREQUENCY OF OCCURRENCE (ORDER OF MAGNITUDE)

PREVAILING ENVIRONMENT WHEN OCCURRENCE WAS NOTED

ESTABLISH FAILURE MECHANISMS

DEVISE ESS TO PRECIPITATE FAILURES AT LOWEST LEVEL

PURGE SYSTEM OF SUSPECT PARTS, IMPLEMENT ESS, TAKE CORRECTIVE ACTION

MONITOR SUCCESS AND FINE TUNE RESULT

* Self-explanatory.

READINESS PHILOSOPHY

PARTS

- "QPL" ONLY MEANS THE SUPPLIER HAD THE FORMULA ONCE, IT DOESN'T GUARANTEE CONSISTENCY
- PROCESS CONTROL CAN'T BE MAINTAINED FOR DESIRED MILITARY NEED
- ESS FOR KNOWN FAILURE MECHANISMS

SYSTEMS

- DON'T FAIL, PARTS FAIL
- ALL USE PARTS FROM THE SAME SUPPLIERS
- ONLY FAIL WHEN THE DESIGN IS NOT FORGIVING
- NEED ESS FOR KNOWN FAILURE MECHANISMS

* Receive and inspection testing is a farce.
  * It's expensive.
  * All tests are DC - only get AC tests in the system.
  * Doesn't precipitate failures.
  * Doesn't detect problems that exist at the system level
  * IMPORTANT: Does give you a gauge to measure supplier by.
* Systems don't fail - parts do. We expect the system to survive 10,000 hours, but we don't process the parts for it.
* Utilize ESS at the lowest level that may far exceed the requirements of the procurement specification for components.
* Militaryspec is too benign to detect problems.
* Unless you have a methodology of work to force fail parts and precipitate out the defects, you'll always end up with somebody else's rejects.

READINESS PHILOSOPHY (Cont.)

RELIABILITY

- SYSTEM REQUIREMENTS, ARE MORE STRINGENT THEN COMPONENT REQUIREMENTS
- ESS FOR KNOWN FAILURE MECHANISMS

ANALYZE DEFECTIVES

- ALL OF THE KNOWLEDGE OF WHAT IS WRONG WITH A SYSTEM IS IN ITS DEFECTIVES
- CORRECT FOR DEFECTIVES AND YOU EVOLVE A PERFECT SYSTEM
- ENSURE CORRECTIVE ACTION THROUGH FEEDBACK SYSTEMS
- DEVISE ESS FOR FAILURE MECHANISMS

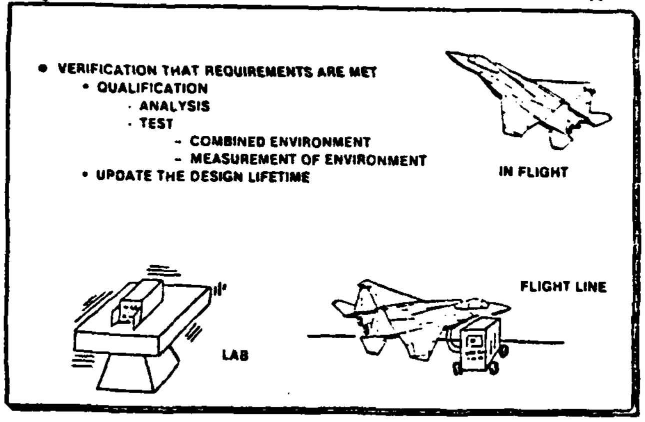
ASSESS ALL STEPS

- PEOPLE PROCESS PARTS/MATERIAL DESIGN

QUALITY IS A STATE OF MIND THAT CAN BE MANAGED

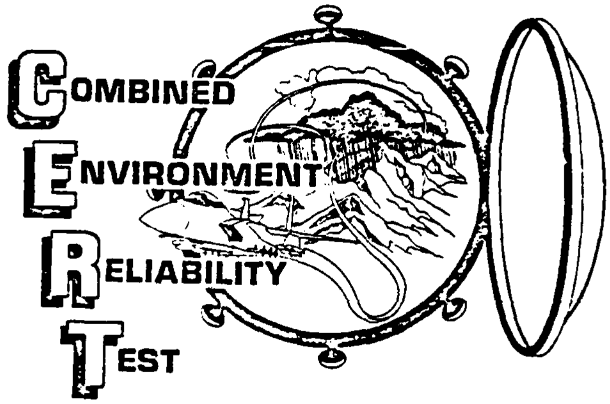
* Reliability is strengthened because parts don't fail - only failures are system nonconformities.
* *If analyze, first rule applies: all* of the knowledge of what's wrong with a system is in your defectives.
  * Assess your defectives
  * Understand the environment in which the parts operate
  * Devise a methodology to force fail parts
* *Part specifications,* as they exist today, will not give you what you need for the aircraft environment.

VERIFY PRODUCT



ACTIV #17
Finally, we want to be sure that the finished product meets the requirements. Verification is accomplished by analysis and/or test.

ACTIV #17
Now, Dr. Alan Burkhard will discuss CERT, Combined Environment Reliability Test.



OVERVIEW

- BACKGROUND
- CERT EVALUATION PROGRAM
- TECHNICAL CONSIDERATIONS TO CONSTRUCTING A CERT PROGRAM

This presentation will cover the following key concepts:

1. *What is CERT?*
2. *A summary of an extensive R&D program to validate the concept.*
3. *Overview of the technical analyses and engineering decision necessary to develop a CERT test profile.*
4. *Examples of recent or current acquisition or logistic programs which have utilized CERT.*

CERT MISCONCEPTIONS

- CERT IS NOT A SPECIFIC
  - TEST PROFILE
  - STRESS RANGE
  - STRESS COMBINATION
  - FACILITY

Before discussing what CERT is it is important to first clarify what it is not. Certain misconceptions concerning CERT often seem to be treated as facts. These misconceptions have not been deliberately perpetrated by any specific individual or organization. Rather incomplete communication.

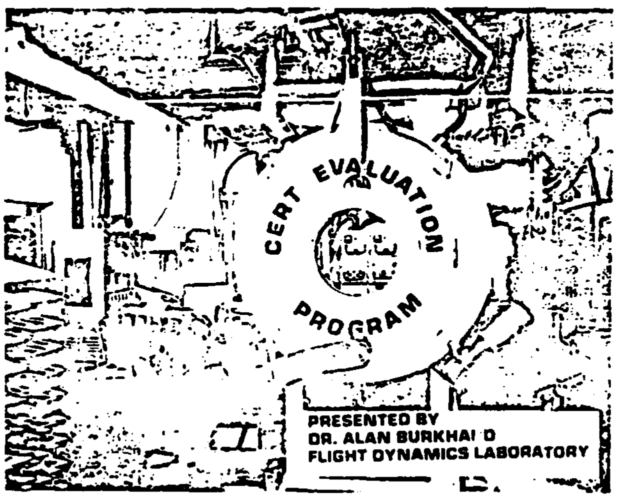
CERT is not a specific test profile or set of environmental stresses, such as acoustic, thermal and humidity. CERT is not limited to an "official" stress amplitudes or stress combinations. CERT is not a specific type of test chamber or a specific test facility at some location.

REALISTIC TESTING

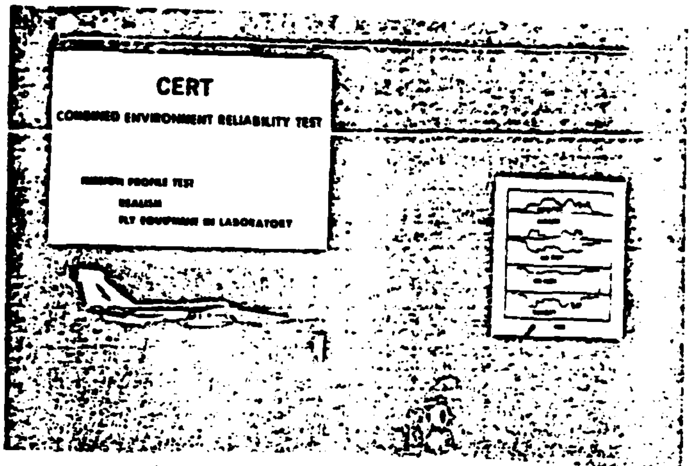
- ENGINEERING APPROACH TO TESTING
- TAILOR TEST CONDITIONS
  - APPLICATION
  - TEST OBJECTIVE
  - EQUIPMENT DESIGN
  - COST EFFECTIVENESS
- APPROACH GIVEN ACRONYM "CERT"
  - COMBINED ENVIRONMENT RELIABILITY TEST

CERT is any laboratory test for hardware reliability, life improvement or characterization in which environmental stresses anticipated in actual usage are combined and applied simultaneously to the test hardware in a sequence which simulates the usage scenarios. The test conditions must be tailored to fit the planned application, test objectives, sensitivities of the hardware design and to be cost effective.*

**Such data can be used as input for estimates of operational readiness, mission success, maintenance manpower and logistic support costs.*

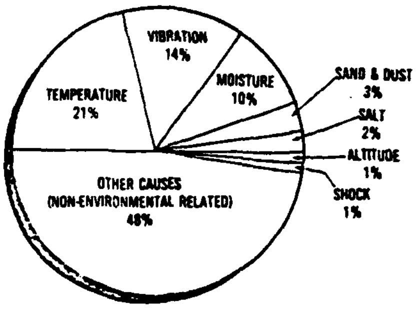


The CERT Evaluation Program was joint Aeronautical Systems Division (ASD) and Air Force Wright Aeronautical Laboratories, Flight Dynamics Laboratory (AFWAL/FIEE) program to evaluate the technical and cost effectiveness of Combined Environment Reliability Test (CERT).



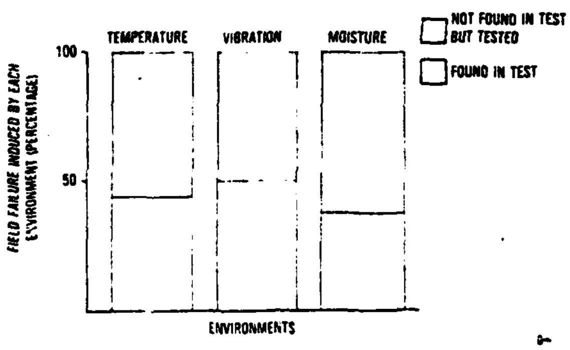
This chart outlines the CERT concept using an internally carried avionics equipment as the example. The equipment is exposed to environmental stresses in the laboratory which causes the item under test to behave as if it was actually being flown within the aircraft.

DISTRIBUTION OF FIELD FAILURE MODES



Studies have found that about 52% of avionics equipment field failures are environmentally induced with temperature, vibration and moisture, humidity being the big three environmental stress parameters.

TEST EFFECTIVENESS



It was found that the environmentally based tests used to identify equipments with environmental sensitivities were not effective. For example 50% of the temperature induced field failures were not observed during predeployment testing. The 40% value represents those failures which were observed during testing but either improper correction actions or nothing was done about them.

BACKGROUND

- CONCEIVED BY AFWAL/FIEE EARLY 1970's
- JOINT ASD/AFWAL/PRAM CERT EVALUATION PROGRAM (NOV 1975 - DEC 1981)
  - DEVELOPED DATA BASE
  - COST EFFECTIVENESS STUDIES
  - DEMONSTRATED PRODUCTIVITY
  - WROTE MILITARY TEST STANDARD

• INTERIM TEST STANDARD - MIL-STD-781C	1977
• DOD - INDUSTRY CERT WORKSHOP	JUNE 1981
• AFSC/AL CERT POLICY LETTER	20 JULY 1982
• ASD/CC CERT POLICY LETTER	28 SEPTEMBER 1982
• FINAL TEST STANDARDS	SEPTEMBER 1982
• AFR 800-18 & AFSC 800-18	JANUARY 1983

The CERT concept was conceived to attack these problems. A joint Aeronautical Systems Division (ASD) and Air Force Wright Aeronautical Laboratories (AFWAL) CERT Evaluation Program was conducted after initial laboratory R&D demonstration of the concept on a radar system.

The CERT Evaluation Program came technical data from which effectiveness assessments of the technique were made. These assessments resulted in AFR 800-18 and AFSC 800-18 policy statements.

CERT EVALUATION PROGRAM

- ACCOMPLISHED
  - EVALUATED 3 LEVELS OF TEST REALISM
  - COMPARED TEST TO FIELD EXPERIENCES
  - PERFORMED TECHNICAL AND COST EFFECTIVENESS ASSESSMENTS
- DEVELOPED DATA BASE OF CERT EXPERIENCE
  - 24,753 TEST HOURS
  - 200 FAILURES
  - 80 DIFFERENT UNITS / SYSTEMS
  - BROAD SPECTRUM OF AVIONICS EQUIPMENTS / AC COMBINATIONS (F-15, A-10, F-5, A-7, F-111, FB-111, F-5)

The CERT Evaluation Program was a massive effort to evaluate the effectiveness of CERT to identify field failure modes. This was accomplished by selecting already fielded systems, conducting CERT tests, comparing test to field failure modes and developing a measure of correlation. The data base generated is shown on this chart.

SCOPE

- COMPARE EFFECTIVENESS OF THREE LEVELS OF TEST REALISM

- CERT I	FULL ENGINEERING APPROACH
- CERT II	CERT I WITHOUT ALTITUDE
- CERT III	TABULAR TEST LEVEL (MIL-STD-781C)

The CERT Evaluation Program compared three levels of test realism. The approach given the label, CERT I, uses full engineering approach in terms of measured data and computer analysis. CERT II was the same as CERT I except no altitude, pressure, variations occurred in the test. This addressed a potential test facility cost savings that would be available if altitude simulation was not required. CERT III used the tabular test levels in MIL-STD-781C Appendix B.

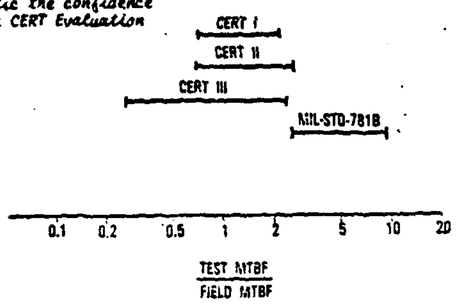
CERT PROGRAM (MTBF)

ITEM	MODEL	PROFILE	MIL-STD 781B	CERT III	CERT II	CERT I	FIELD
			MTBF IN HOURS				
RADIO	ARC-164	A-7	1000	-	-	87	149
IFF	APX-76	F-15	1748	85	-	104	133
INU	ASN-90	A-7	1885	225*	-	235*	156
RADIO	ARC-109	F-111	619	696	142	145	95
IFF	APX-101	F-15	762	58	252	504	273
TACAN	ARN-84	F-5	670	187	157	160	170
IFF	APX-101	A-10	762	334	899	1010*	382
TACAN	ARN-84	FB-111	670	279	724	1114	187

*[illegible] FAILURES

This chart summarizes the results of the CERT Evaluation Program in terms of MTBF values. The MIL-STD-781B MTBF values shown on this chart were not generated as part of this program. These are the original MTBF values that were either demonstrated on the stated requirements when these equipments were purchased. These values are included for reference purpose recognizing that the definition of failure may have been different for these tests. The field MTBF values are the raw AFM 66-1 data for the same time frame as when the CERT tests were conducted on that equipment system. The definition of failure used in CERT was the same as that used by AFM 66-1.

90% CONFIDENCE BANDS ON TEST-TO-FIELD MTBF RATIOS



This chart summarizes the data shown on the previous chart in terms of confidence bands on normalized MTBF ratios, test to field values. Two trends are visible: (1) all three CERT tests have a lower test to field MTBF ratio than previously used testing, less optimistic estimated MTBF values and (2) as the tests become more environmentally realistic the confidence bands become narrower. The finds from this and other data generated during the CERT Evaluation Program is summarized on the next four charts.

FINDINGS FROM CERT EVALUATION PROGRAM

- ALL CERT FAILURES-FIELD RELEVANT
- IMPROVED CONSISTENCY OF ESTIMATED FIELD FAILURE RATE FROM TEST DATA
  - 4 TO 1 IMPROVEMENT OVER PREVIOUS METHODS

The effectiveness of CERT testing was made on four different basis: correlation of failure modes and rates between CERT and field, the cost of doing CERT testing as compared to cost of other testing approaches and on a life cycle cost basis.

Everything, every part, sooner or later fails, in the field due to normal or misuse. Therefore, it was decided to evaluate whether or not the CERT failure modes occur in significent quantity. The logic was that failures that occurred repeatly were not those due to misuse. It was found that all CERT induced failure modes occur in significant quantity during deployment, e.g., all CERT failures were field relevant.

The CERT approach to testing yeilds more consistent estimates of field failure rates in that the MTBF values more truely reflect field experience. Additionally, the number of test hours to reach a statistically significant decision point is less since the test items fails at a more realistic, rapid, rate.

FINDINGS FROM CERT EVALUATION PROGRAM

- COMBINED VERSUS SINGLE ENVIRONMENT TESTING
  - IDENTIFIES SIGNIFICANT FIELD FAILURES UNDETECTED BY SINGLE ENVIRONMENT TESTING
- NEED FOR ALTITUDE
  - JUSTIFY ON CASE BY CASE BASIS

All the equipments used in the CERT Evaluation Program had previously undergone conventional single environment testing during their initial acquisition programs. The results of this single environment testing was compared to the results of the CERT testing. It was found that seven major field failure modes were detected by CERT which were not detected by single environment testing. Also failure modes found during single environment testing that were not corrected were also identified during CERT testing.

The test results found that altitude, pressure variations, during CERT was not necessary except for systems with obvious sensitivities to pressure changes; e.g., high voltages, vacuum sealed sections, etc. Therefore, a decision as to the need for altitude change simulation needs to be done on a case by case basis.

FINDINGS FROM CERT EVALUATION PROGRAM

- CERT COST EFFECTIVENESS
  - ON LIFE CYCLE BASIS
    AVERAGE RETURN ON INVESTMENT 2-4 YEARS
  - ONE TEST IN PLACE OF UP TO 6 TESTS
  - TEST CHAMBER COSTS COMPETITIVE ($250-800K)
  - TEST OPERATION COSTS

On a Life Cycle Cost (LCC) basis for the equipments tested in the CERT Evaluation Program it was found that if CERT would have been used during the original acquisition of these equipments the average return on investment would have been with two to four years after deployment. This costing was done by the original equipment manufacturer who evaluated the costs of using a more effective test method, e.g., more failures, doing failure analysis, design changes, production line changes, etc.

Because the environmental stresses are combined, up to six sequential single environment tests can be replaced by one CERT test. This precipitates many potential cost savings available to an acquisition program office, e.g., fewer test items to purchase, fewer electronic test setups, one test sequence instead of six, etc. The cost of test chamber and operation are not significantly different than conventional testing.

APPLICATIONS OF CERT

- RELIABILITY DEMONSTRATION
- RELIABILITY GROWTH
  - TEST-ANALYZE-FIX
- ENVIRONMENTAL QUALIFICATION
- FLIGHT / OPERATIONAL SUPPORT
- PRODUCTION VERIFICATION

Reflecting upon the definition of CERT one can see how CERT is appropriate for all environmentally based testing. This chart lists several such tests for which CERT test conditions are appropriate.

USES OF CERT IN ACQUISITION PROCESS

- EVALUATE COMPETITIVE DESIGN
  - AIDS SOURCE SELECTION DECISION
  - HEAD TO HEAD FLY OFF'S
- VERIFY CONTRACT COMPLIANCE
- COMPREHENSIVE GROWTH TESTING
  - STIMULATES GROWTH UNDER TOTAL DEPLOYMENT STRESS ENVIRONMENT
- EVALUATE ECP PROPOSALS
- FLIGHT TEST SUPPORT
  - ENVIRONMENTAL WORTHINESS

These are five potential benefits of using CERT test conditions in acquisition environmentally based testing. Each point will be discussed in detail over the next few charts.

BENEFITS OF CERT IN ACQUISITION PROCESS

- REALISTIC REQUIREMENTS
- ACCELERATE ACQUISITION CYCLE
- IMPROVE PRODUCTIVITY OF FLIGHT TESTING
- REDUCE ENVIRONMENTAL / RELIABILITY TEST COSTS
- IMPROVE LOGISTIC SUPPORTABILITY

CERT can/has been used to accomplish these objectives within the acquisition process. The benefits of such testing will be outlined in the next few charts.

REALISTIC REQUIREMENTS

- ENGINEER TESTS
  - REDUCE DUMB REQUIREMENTS
  - REDUCE COST DRIVERS
- MODERATE STATED OPERATIONAL REQUIREMENTS
  - ASK FOR X INSTEAD OF 10X TO GET X
- EQUIPMENT STANDARDIZATION
  - STANDARDIZATION ON DESIGN
  - TAILOR REQUIREMENTS

    FOR EXAMPLE: AN/ARN-XYZ REQUIREMENTS

A/C	MTBF
C-130	1050
F-15	425
B-52	2000
UH-60	25

If requirements are stated realistically then the proper part quality could be used rather than going to the higher cost of using "high rel" parts when not necessary. Standardization has for too long been on requirements independent of application. Standardization should be on product design recognizing that level of reliability and logistic sparing requirements are a function of application.

ACCELERATE ACQUISITION CYCLE

- ONE TEST IN PLACE OF UP TO 6 TESTS
  - ONLY ONE TEST SET-UP
  - FEWER TEST ITEMS NEEDED
- ACCUMULATE MONTHS OF OPERATION UNDER DEPLOYMENT STRESSES IN ONLY WEEKS OF TESTING
  - CONCURRENT DEVELOPMENT AND PRODUCTION
  - LEAD THE INVENTORY (FLEET)
    - FIND PROBLEMS IN LAB BEFORE FIELD
- TEST CONFIDENCE BUILDS FASTER ≈ 4X

CERT can reduce program schedule time allocated to testing since up to six tests can be replaced by one CERT test. CERT can help to accelerate accelerated development programs which use concurrent development and production. One equipment system can be put under CERT testing and within one calendar month evaluate the system for up to 13 months of actual usage. This lead the inventory (fleet) testing will identify problems before they occur in the field and provide sufficient time for corrective actions to be developed before the deployed systems start to fail.

IMPROVE PRODUCTIVITY OF FLIGHT TESTING

- ELIMINATE ABORTED MISSIONS CAUSED BY ENVIRONMENTAL STRESSES
  - IDENTIFY ENVIRONMENT SENSITIVITIES BEFORE FLIGHT TESTING
  - USE SAME ITEM FOR BOTH CERT AND FLIGHT TEST
  - SWAP AMONG LAB AND FLIGHT TEST TO TRACK DOWN PERFORMANCE PROBLEM DURING FLIGHT TESTING
- CERT << COST OF FLIGHT TESTING
  - < 1000 TO ONE RETURN ON INVESTMENT

A major contributor to unproductive flight testing is unanticipated failures of the equipment under test. A short CERT test before flight testing can shake down the test items to remove environment sensitivities before they abort test flights. During flight test an abnormal behavior may be observed and the test item can be taken out of flight testing and checked under controlled CERT conditions. Since CERT conditions are realistic, there are no test unique stress states imposed on the test items. Thus, the test items can be swapped between laboratory and flight testing. Major cost savings can be realized since CERT testing is significantly less costly than flight testing on a per test hour basis.

REDUCE ENVIRONMENTAL / RELIABILITY TEST COSTS

- ONE TEST IN PLACE OF SEPARATE

VIBRATION	ALTITUDE
THERMAL	ELECTRICAL VARIATIONS
HUMIDITY	RELIABILITY DEMONSTRATION
	COOLING AIR FLOW

- EXAMPLE OF POTENTIAL COST SAVINGS

DELETE 7 SEPARATE ENVIRONMENT TESTS	$195,000
DELETE RELIABILITY DEMONSTRATION TEST	850,000
REPLACE WITH SINGLE CERT GROWTH TEST	230,000
COST SAVINGS	$815,400

This cost savings was the savings realized by the program office which developed the AN/ARN-131, OMEGA, Navigation System.

IMPROVE LOGISTIC SUPPORTABILITY

- REDUCE FALSE REMOVAL RATE
  - IDENTIFIES VOLATILE MALFUNCTIONS TRIGGERED BY SPECIFIC STRESS COMBINATIONS / STATES
  - 26% OF BCS ARE ENVIRONMENTALLY INDUCED
  - APPROPRIATE FOR REPAIR PROCESS
- IMPROVED ESTIMATES OF FIELD RELIABILITY FROM TEST DATA
  - MORE ACCURATE LOGISTIC PLANNING
    - NUMBER OF SPARES
    - WHAT TO SPARE
- EVALUATE EFFECTIVENESS OF ELECTRONIC SUPPORT EQUIPMENT

A major cause of high logistics costs is the high false removal rate of many avionics systems. A detailed study of the bench checked serviceable (BCS) maintenance actions found that 26% of BCS were environmentally induced. This is the environment only malfunctions under a specific set of environmental stresses and once the stresses are removed the malfunction goes away. A CERT test flys the equipment in the laboratory so that inflight and after flight maintenance and checkout procedures can be evaluated for their effectiveness.

EMPHASIS ON TAILORING

- HAVE TO BE AN INFORMED AVOCATE
  - WEAPONS OF AVOCACY
  - HOMEWORK DONE
  - PUT YOURSELF IN THEIR SHOES
  - KNOW COST VERSUS BENEFITS

Effective CERT test planning requires the test engineer to consider both technical and management factors to construct the most appropriate CERT test profiles.

CHANGING ACQUISITION ENVIRONMENT

TAILORING OF REQUIREMENTS

- NO SACRED COWS
- NO PREORDAINED COMBINATIONS OF ENVIRONMENTS
- REFLECTED IN MIL-STD-781C AND MIL-STD-810D

The CERT testing approach is being reflected throughout the entire DoD environmentally based testing military standard documents. These documents suggest and give rationale for selection of a specific set or combination of environments. The test planner makes the final determination. CERT procedures for aircraft internally carried equipment and externally carried stores are Test Methods 520 and 523 of MIL-STD-810D respectively. Reliability demonstration test procedures for internally carried electronic systems are included in MIL-STD-781C.

WHAT GUIDES ARE AVAILABLE

- MIL-STD-785
- MIL-STD-781
- MIL-STD-810
- MIL-STD-1670
- AF PHAMPLET 800-9
- DATA ITEMS

These documents provide guidance on tailoring. Tailoring can be done at many different levels within an acquisition program, e.g., selection of appropriate tasks to be accomplished, design and test conditions, hardware design sensitivities, etc.

DATA ITEMS

• ENVIRONMENTAL DEVELOPMENT PLAN (EDP)	DI-R-7123
• ENVIRONMENTAL PROFILE REPORT (EPR)	DI-R-7124
• ENVIRONMENTAL CRITERIA & TESTING DOCUMENT (EDCTC)	DI-R-7125
ENVIRONMENTAL TEST REPORT	DI-R-7127
OPERATIONAL ENVIRONMENT VERIFICATION REPORT (OEVR)	DI-R-7126
ENVIRONMENTAL CRITERIA REPORT	DI-T-1119
RELIABILITY TEST PLAN	DI-R-7003
ENVIRONMENTAL RELIABILITY REPORT	DI-R-2116

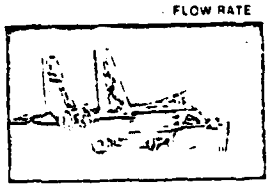
This chart lists the appropriate data items available for properly documenting a CERT test. The starred data items should be used regardless of the purpose of the test program, growth, demonstration, flight worthiness, or qualification.

TRACK ENVIRONMENT

DURABILITY: ENDURANCE, LIFE

PREDICTION ⟶ LAB TEST ⟶ ACTUAL USAGE ⟶ REVISED LIFE

- BUILD STATISTICAL DATA BASE
- RECORDING PROGRAM
  - INSTRUMENTATION OF SELECTED AIRCRAFT
    - TRANSIENTS
    - TEMPERATURE (IN FLIGHT AND ON GROUND)
    - VIBRATION
    - FLOW RATE



ACTIV #18
Now that the product is deployed we need to record key data to see if the actual environment is what we originally assumed it to be and to determine how the equipment is surviving in the environment.

ACTIV #1, 2, 11, 20
Mr. Ken Morris is here to explain how the logistics organization can help in improving our avionics systems.

PURPOSE:

- PROVIDE A TECHNIQUE TO INFLUENCE MISSION HARDWARE DESIGN AND DEVELOP A SUPPORT CAPABILITY

BACKGROUND:

- NAVY INITIATED 1970
- FORMALLY PUBLISHED 1973
- AIR FORCE INITIATIVE 1978
- JOINT SERVICE/INDUSTRY WORKSHOP 1979
- LEADERSHIP ASSUMED BY OSD(MRA&L) 1980
- REWRITE MIL-STD 1388-1 (ANALYSIS REQUIREMENTS)
- REVISE MIL-STD 1388-2 (LSAR)

LOGISTICS SUPPORT ANALYSIS (LSA)

- ILS IDENTIFIED AS A FUNCTION OF SYSTEMS ENGINEERING (MIL-STD 499A)
- HISTORICALLY MANAGEMENT PARTITIONED DESIGN AND SUPPORT FUNCTIONS
- LOGISTICIANS ASSUMED PASSIVE ROLE UNTIL DESIGN WAS KNOWN
- RECOGNIZE THAT AN ITEM'S SUPPORT CHARACTERISTIC IS HEAVILY INFLUENCED BY THE DESIGN ACTIVITY

ENGINEERING

- *ASSISTS IN* THE DEVELOPMENT OF SUPPORTABLE SYSTEMS OR EQUIPMENT
- CONTROLS THE FORM AND FUNCTION OF THE SUPPORT PLANNING PROCESS

- LSA PROGRAM RESTRUCTURED TO ESTABLISH A ROLE FOR THE LOGISTICIAN IN THE DESIGN PROCESS
- TASKS ORIENTED TOWARD HIGHLIGHTING SUPPORT AS A DESIGN CONSIDERATION
- EARLY EMPHASIS ON SUPPORT PLANNING

PURPOSE

ESTABLISH WITHIN ENGINEERING THE TOOLS AND TECHNIQUES FOR DEVELOPING SUPPORTABLE SYSTEMS AND EQUIPMENTS.

- INFLUENCING DESIGN
- SUPPORT PLANNING

AVIONICS INTEGRITY PROGRAM ESTABLISHED TO PROVIDE THE FRAME WORK OF REQUIRED ACTIVITIES TO IMPROVE AVAILABILITY AT MINIMUM LIFE CYCLE COST

- ESTABLISH UNITY OF PURPOSE IN ACHIEVING OVERALL PROGRAM REQUIREMENTS

LOGISTICS SUPPORT ANALYSIS PROPERLY APPLIED TAKES ON THE FORM OF AN ENGINEERING DISCIPLINE

- SUPPLEMENTS ENGINEERING REQUIREMENTS
- ESTABLISHES INTERDEPENDANCIES WITH OTHER ENGINEERING DISCIPLINES

AVIP - LSA RELATIONSHIP

AVIP	LSA
ENGINEERING MANAGEMENT TOOL	ENGINEERING DISCIPLINE
o ENVIRONMENT DEFINITION	o USE STUDY
o RELIABILITY	o COMPARATIVE ANALYSIS
o MANUFACTURING	o SUPPORTABILITY CONSTRAINTS
o ECONOMIC LIFE	o O&S COSTS
o MAINTAINABILITY	o ANALYSIS/TRADE-OFF
o SOFTWARE DEVELOPMENT	

LOGISTICS SUPPORT ANALYSIS

LSA

- **IDENTIFY LOGISTICS DESIGN CONSTRAINTS & RISKS**
- **INFLUENCES THE DESIGN**
- **IDENTIFIES THE SUPPORT NEEDS**
- **INTEGRATES THE ILS EFFORT**

- LOGISTICS SUPPORT ANALYSIS VARY DEPENDING ON DESIGN ACTIVITY
- EARLY PROGRAM ACTIVITY LIMITED TO THOSE TASKS ASSOCIATED WITH IDENTIFYING DESIGN RELATED SUPPORT REQUIREMENTS
- AS DESIGN PROGRESS LOGISTICS SUPPORT ANALYSIS TASKS ASSOCIATED WITH DEVELOPING THE SUPPORT SYSTEM COME INTO PLAY
- THE LSA TASKS ASSOCIATED WITH THE ADVANCED TACTICAL FIGHTER PROGRAM EXEMPLIFY THE EARLY ANALYTICAL ACTIVITY
- THE SAME TASKS WILL ALSO BE EVIDENT IN THE ADVANCED TACTICAL RADAR PROGRAM, PAVE PILLAR, ICNIA, INEWS, AND ADVANCED FIGHTER ENGINE

STRUCTURE OF STATEMENT OF WORK

MAIN BODY

- GENERAL LSA DIRECTION

ANNEX M (LOGISTICS ENGINEERING)

SECTION 1 = LSA TASKING
SECTION 2 = AREAS OF CONCERN
SECTION 3 = LESSONS LEARNED
SECTION 4 = EMERGING TECHNOLOGY

- LSA TASKS MAY BE CONTRACTUALLY REQUIRED OR ACCOMPLISHED IN HOUSE
- ATF PROGRAM LSA TASKS ARE CONTRACTUALLY REQUIRED
- GENERAL LSA DIRECTION, INTERFACE REQUIREMENTS ARE INCLUDED IN THE BASIC RFP
- LOGISTICS ENGINEERING SECTION INCORPORATES ALL LOGISTICS REQUIREMENTS. SOME R&M REQUIREMENTS INCORPORATED IN LSA SECTION

LSA REQUIREMENTS (SECTION 1) MIL-STD-1388A (NOV 81)

GENERAL TASKS

- USE STUDY
- COMPARATIVE ANALYSIS
- TECHNOLOGICAL OPPORTUNITIES
- OBJECTIVES, GOALS, THRESHOLDS, CONSTRAINTS AND RISKS
- FUNCTIONAL REQUIREMENTS IDENTIFICATION
- SUPPORT SYSTEM ALTERNATIVES
- EVALUATION OF ALTERNATIVES/TRADE-OFF ANALYSIS

- THE MAIN BODY OF THE ATF CONTAINS GENERAL STATEMENTS ON THE GOALS AND OBJECTIVES OF THE LSA REQUIREMENTS
- PROVIDES INSIGHT INTO THE INTERDEPENDANCIES OF TASK REQUIREMENTS
- RELATIONSHIP OF LSA TO TOTAL ATF PROGRAM OBJECTIVES

LSA REQUIREMENTS

TASKS	TITLE	SUBTASKS
201	USE STUDY	201.2.1 201.2.2 201.2.4
203	COMPARATIVE ANALYSIS	203.2.1 THRU 203.2.9
204	TECHNOLOGICAL OPPORTUNITIES	204.2.1 THRU 204.2.3
301 & 302	FUNCTIONAL REQUIREMENTS IDENTIFICATION	301.2.1 301.2.2 301.2.3 301.2.5 301.2.6 302.2.1 THRU 302.2.6
303	EVALUATION OF ALTERNATIVES/ TRADE-OFF ANALYSIS	303.2.1 THRU 303.3.11 (EXCLUDING 303.2.7)
205	DESIGN OBJECTIVES, GOALS, THRESHOLDS, CONSTRAINTS, RISKS	205.2.1 THRU 205.2.4

CONTAINED IN THE ANNEX TO RFP ARE THE SPECIFIC LSA TASK REQUIREMENT

TASKS SELECTED ARE THOSE APPLICABLE TO CONCEPT FORMULATION ACTIVITY

OBJECTIVE OF EACH TASK IS:

- USE STUDY = REFERENCE MATERIAL TAF DRAFT SON, SYSTEM READINESS OBJECTIVES, AIR FORCE 2000, AND TAC MAINTENANCE CONCEPT
- COMPARATIVE ANALYSIS = EXAMINE OPERATIONAL FIGHTERS TO IDENTIFY PERFORMANCE AND SUPPORT CHARACTERISTICS INCLUDING HIGH FAILURE ITEMS, MAINTENANCE EXPERIENCE, SKILL LEVELS, COST DRIVERS, ETC.
- TECHNOLOGICAL OPPORTUNITIES = REVIEW EXISTING OR EMERGING TECHNOLOGY FOR POTENTIAL APPLICATION TO ATF SYSTEM
- FUNCTIONAL REQUIREMENTS = IDENTIFY BASIC SYSTEM AND SUPPORT SYSTEM FUNCTIONAL REQUIREMENTS (E.G., PREFLIGHT, POSTFLIGHT, STORAGE RECONFIGURATIONS)
- EVALUATION OF ALTERNATIVES/TRADE OFF ANALYSIS = EVALUATE EACH AIRCRAFT AND SUPPORT SYSTEM ALTERNATIVE. IMPACT OF ALTERNATIVE BASING, OPERATIONS, AND MAINTENANCE CONCEPT
- DESIGN OBJECTIVES, GOALS, THRESHOLDS, CONSTRAINTS, AND RISKS = PREPARE AN OBJECTIVES, GOALS, THRESHOLDS, CONSTRAINTS, AND RISK DOCUMENT. (IDENTIFY KEY COST, SCHEDULE, PERFORMANCE AND READINESS OBJECTIVES AND THEIR IMPACT OF DESIGN AND SUPPORT CONCEPTS

AREAS OF CONCERN (SECTION 2)

SECTION 2 IDENTIFIED 14 AREAS OF CONCERN THAT DIRECTLY IMPACTED LOGISTICS. THESE AREAS COVERED A WIDE RANGE OF AREAS. (E.G., BIT, BATTLE DAMAGE REPAIR, STRUCTURAL MATERIAL, AND AUXILIARY POWER)

THE CONTRACTOR MUST RESPOND TO THESE ISSUES. THEIR RESPONSE WILL BE PART OF THE PROPOSAL PACKAGE.

AREAS SELECTED ARE APPROPRIATE CONCERNS DURING THE CONCEPT FORMULATION PHASE.

- 19 SPECIFIC AREAS TO BE INVESTIGATED

  EXAMPLES:
  - INTEGRATED DIAGNOSTICS
  - AUTOMATED TECH ORDER SYSTEM
  - ACCESSIBILITY
- REQUIRES RESPONSE

LESSONS LEARNED (SECTION 3)

LESSONS LEARNED

- LESSONS LEARNED EXTRACTED FROM THE AFALC DATA BANK (40 INPUTS)
- CONTRACTOR NOT REQUIRED TO RESPOND
- PURPOSE WAS TO PROVIDE INFORMATION TO THE CONTRACTOR ON THE AIR FORCE PAST EXPERIENCES WITH AIRCRAFT

- INFORMATIVE DATA
- NO RESPONSE REQUIRED
- EXAMPLES:
  - INSTRUMENT LIGHTING SYSTEM
  - ELECTRICAL SYSTEM
  - ENERGY HEATING EFFECTS
  - REFUELING

EMERGING TECHNOLOGY (SECTION 4)

- **PURPOSE:** ENCOURAGE APPLICATION OF ADVANCE TECHNOLOGY (LABORATORY PROJECTS)
  - EXAMPLES:
    - FIBER OPTICS
    - COMPOSITES
    - DIRECTED ENERGY WEAPONS
    - AUTOMATED TECH ORDER SYSTEM
    - MULTIPLE INTEGRATED POWER UNIT

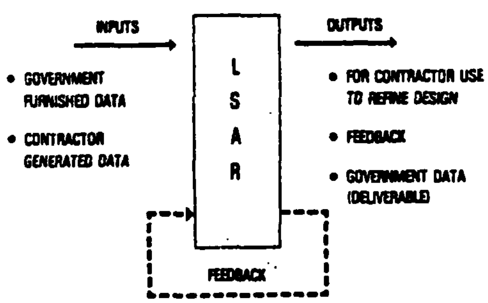
- SECTION 4 OF THE ANNEX WAS TARGETED TOWARD EASING THE TRANSFER OF NEW TECHNOLOGY
- IT IS IMPORTANT IN THAT TECHNOLOGY CONSIDERATIONS INCLUDE NOT ONLY THOSE APPLICABLE TO HARDWARE, BUT THOSE TECHNOLOGY ADVANCEMENTS THAT CAN BE APPLIED TO THE SUPPORT SYSTEM

CDRL

DI-S-30559	TECHNICAL OPERATING REQUIREMENT SUPPORTABILITY ANALYSIS
DI-S-3591A	TECHNICAL REPORT SUPPORTABILITY ANALYSIS

- LOGISTICS DATA REQUIRED FOR DELIVERY LIMITED TO THE RESULTS ON LSA TASK REQUIREMENTS
- USE CONTRACTOR FORMAT
- PROVIDE INPUT TO NEXT PHASE

LSA PROCESS



- HISTORICALLY LOGISTICIAN FAILED TO USE ENGINEERING DATA FOR SUPPORT PLANNING
- DATA DEVELOPED WITHIN ENGINEERING PROCESS REFLECTS THE SUPPORTABILITY CHARACTERISTICS OF THE END ITEM
- THE LSAR IS AN APPROACH TO INTEGRATING THE DATA AND MAKING IT AVAILABLE TO LOGISTICIANS

LSAR DATA
(TRACEABILITY - VISIBILITY)

ORIGIN	RECORD	USED FOR
SYSTEM SPECIFICATION STATEMENT OF NEED MISSION ELEMENT NEED STATEMENT	A	ANALYSIS TRADE STUDY SUPPORT PLANNING DATE
MIL-STD 785B MIL- STD 1629A MIL-H 266 MSG-3	B	
MIL-STD 470 MIL-STD 1472B	C - D	
SERD (DID 3596A)	E	
MIL-STD 831	F	
MIL-STD 46855	G	
MIL-STD 1552 MIL-STD 1367A	H	
MIL-STD 1366 MIL-STD 1367	J	

FULLY COORDINATED WITHIN AFLC/AFSC - OTHER SERVICE'S - INDUSTRY

- RECORD CONTAINS BOTH GOVERNMENT AND CONTRACTOR DATA
- DATA TRACEABLE TO ENGINEERING STANDARD (EXCEPT SUPPORT EQUIPMENT)
- PROPERLY CONSTRUCTED DATA BASE PROVIDES TRACEABILITY BETWEEN OPERATIONAL REQUIREMENTS, R&M RESULTS, AND SUPPORT REQUIREMENTS

LOGISTICS SUPPORT ANALYSIS

DATA SHEETS - INPUTS

"A" OPERATIONS AND MAINTENANCE REQUIREMENTS
"B" ITEM RELIABILITY (R) AND MAINTAINABILITY (M) CHARACTERISTICS
"C" TASK ANALYSIS SUMMARY
"D" MAINTENANCE AND OPERATOR TASK ANALYSIS
"E" SUPPORT AND TEST EQUIPMENT OR TRAINING MATERIAL DESCRIPTION AND JUSTIFICATION
"F" FACILITY DESCRIPTION AND JUSTIFICATION
"G" SKILL EVALUATION AND JUSTIFICATION
"H" SUPPLY SUPPORT REQUIREMENTS
"I" AUTOMATIC TESTING EQUIPMENT/TEST PROGRAM SET DESCRIPTION
"J" TRANSPORTABILITY ENGINEERING CHARACTERISTICS

LOGISTICS SUPPORT ANALYSIS

- DATA CONTAINED IN THE LSAR PROVIDES THE KEY TO SUPPORT PLANNING PROCESS
- USED IN TRADE STUDIES
- PROVIDES DATA TO PROJECT O&S COSTS

PROGRAM STATUS

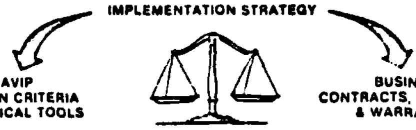
- NAECON
- DRAFT MIL-STD
- INDUSTRIAL FORUM
- PROGRAM APPLICATIONS UNDER INVESTIGATION
  - ADVANCED TACTICAL FIGHTER
  - LABORATORY PROGRAMS
  - OTHERS

Integrity is the central theme of this years' NAECON, "Operational Readiness through Electronic Integrity". The Avionic Integrity Program's main responsibility is to develop a draft MIL-PRIME-STD which will be reviewed at an industrial forum later this year. This MIL-PRIME will be applied in the near future to such programs as the Advanced Tactical Fighter (ATF), various laboratory programs, and other avionics programs.

CONCLUSIONS

- IMPROVED AVIONICS INTEGRITY
- APPROACH: DETERMINISTIC PHILOSOPHY
  - DURABILITY
- CONTROL: SERIES OF ACTIVITIES
  - STRESS ANALYSIS
  - DESIGN TO STRESS
  - STRESS SCREENING
  - PROCESS
- METHOD: DESIGN CRITERIA/TOOLS
  MASTER PLAN
  DESIGN REVIEWS

IMPLEMENTATION STRATEGY



AVIP
DESIGN CRITERIA
TECHNICAL TOOLS

BUSINESS
CONTRACTS, INCENTIVES
& WARRANTIES

Avionics integrity is necessary for improved avionics availability and readiness. This integrity needs to be obtained through a balance of technical and business tools. On the technical side a more deterministic approach is necessary and can obtained through the control of the series of activities we have listed here and through the management methods as outlined by the AVIP. The contractual strategies must thus be applied along with the technical requirements. The strategy implementation is the responsibility of the ASD Assistant for Product Assurance, Dr. John Halpin.

GE WINS BATTLE IN JET "WAR" *

MR. GEORGE H. WARD - GENERAL MANAGER OF MILITARY ENGINE PROJECTS, EVENDALE, OHIO

"WE'VE NOT SACRIFICED DURABILITY FOR PERFORMANCE, WE'VE MADE DURABILITY AND RELIABILITY AND THE ABILITY FOR THE PILOT TO MOVE THE THROTTLE NO. 1 AND WE'VE TRADED PERFORMANCE AND EVERYTHING ELSE FOR IT."

"WE FELT THAT FOR THERE TO BE THE BASIS FOR COMPETITION, IT HAD TO RESOLVE AROUND DURABILITY."

*DAYTON DAILY NEWS, SUNDAY, 4 MAR 84

The Engine Structural Integrity Program has achieved success and influences engine acquisition at ASD as the recent GE contract in the alternate engine program attests. The Avionics Integrity Program is to follow in this tradition.

END

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